

1           NEAR-INFRARED REFLECTING, ULTRAVIOLET PROTECTED,  
          SAFETY PROTECTED, ELECTROCHROMIC VEHICULAR GLAZING

Cross-Reference To Related Applications

          This application is a continuation-in-part of  
5       prior pending application Serial No. 07/464,888 filed  
January 16, 1990, now issued as U.S. Patent No. \_\_\_\_\_,  
which is a continuation-in-part of prior pending application  
Serial No. 07/155,256, filed February 12, 1988, now  
abandoned.

10                   BACKGROUND OF THE INVENTION

          This invention relates to electro-optic devices  
for vehicles and, more particularly, to an enhanced  
vehicular rearview mirror or window glazing incorporating an  
electro-optic medium allowing variation in the transmission  
15       of light in response to application of an electric field to  
the electro-optic medium.

          Specifically, in one aspect, the invention is a  
variable reflectance, electro-optic mirror including  
protection against laceration injuries and scattering of  
20       glass or other fragments if broken or damaged, against  
degradation from ultraviolet radiation, and against fogging  
and misting in high humidity conditions.

          This invention also relates to glazing in vehicles  
and, more particularly, to an enhanced vehicular window, sun  
25       visor, shade band or sunroof incorporating an electrochromic  
medium allowing variation in the light transmitted by the  
glazing in response to application of an electric field to  
the electrochromic medium. Specifically, the invention is a  
variable transmission, electrochromic vehicular window  
30       including protection against laceration injuries and  
scattering of glass, other fragments, or chemicals if broken

1 or damaged, against degradation from ultraviolet radiation,  
and including thin film means to reflect a substantial  
portion of incident, solar, near-infrared radiation.  
Optionally, and preferably, the electrochromic glazing  
5 assembly is blue or green in transmission, as viewed from  
the vehicle interior, so as to reduce glare from the sun and  
to optimize visibility and a true-to-nature blue view of the  
sky.

10 In a collision, the glass typically used as the  
substrate in vehicular rearview mirrors poses potential  
hazards to the driver or other vehicle occupants. Since  
glass easily shatters into sharp, irregular fragments, there  
is a high likelihood of facial or other injury, typically  
lacerative in nature, in any collision. For this reason,  
15 prior known interior and exterior vehicular rearview  
mirrors, which typically consist of a single glass piece  
coated with reflective material, are conventionally  
protected by applying a tape or a plastisol-type plastic  
adhesive to the back surface of the glass piece.  
20 Accordingly, if impacted or broken in an accident, and  
shattered, glass fragments are retained by the tape or  
plastisol-type plastic adhesive.

25 More recently, however, a new generation of  
electro-optical mirrors has emerged which are fabricated  
using two pieces of glass separated by a gap or space which  
contains an electro-optic medium allowing variation in the  
light reflected by the assembly. For example, in liquid  
crystal rearview mirrors, the space between the transparent  
front and reflective coated rear glass pieces is filled with  
30 a semi-viscous liquid crystal material. In  
electrochemichromic or electrochromic mirrors, the gap or

1 space contains a liquid, thickened liquid, gel or semi-solid material.

In these types of electro-optic, laminated mirror assemblies, scatterproofing of the rear glass piece is relatively easy since tape or plastisol-type plastic adhesives can be applied to its rear surface behind the reflective coating in the conventionally known manner. However, scatterproofing the front piece of glass in such a laminated assembly is difficult since the material used to fill the space between the front and rear glass pieces is usually insufficiently viscous or adhering to retain fragments of the front glass should it shatter in a collision.

Another problem encountered with electro-optic rearview mirrors and windows or glazing assemblies is degradation due to exposure to ultraviolet radiation over the life of the mirror or glazing. Ultraviolet (UV) radiation from the sun which penetrates the earth's atmosphere has a wavelength in the range between 290 and 400 nanometers (nm) and can cause breakdown in the operational characteristics of the electro-optical medium including chain scission, cross-linking and stimulation of chemical changes in the chemicals used to formulate the electro-optical medium. This interferes with electronic conjugation in the aromatic conjugated materials typically used and thus the electro-optic activity of those materials is impaired. Moreover, the medium will often discolor taking on a yellowish tint visible in light reflected or passing therethrough and drastically affect the usefulness of the rearview mirror or window. Such degradation from UV solar radiation is particularly problematic in

1 electro-optical automotive windows which are typically  
exposed to the full solar radiation, often when the  
electro-optical medium is in its colored state.

5 In order to overcome ultraviolet radiation  
degradation in such electro-optic rearview mirrors and  
glazings, it is possible to add UV radiation absorbing  
materials to the electro-optic medium. However, such UV  
absorbing additives, especially in higher concentrations and  
with broad UV absorbance, themselves impart a yellowish tint  
10 to the materials to which they are added. Such yellow tint  
is also visible in light reflected or transmitted  
therethrough. Yellow is aesthetically displeasing in many  
applications, and is particularly displeasing when used in  
rearview mirrors. Consumer acceptance of rearview mirrors  
15 having a yellowish tint or cast in the reflected light has  
been poor. Moreover, yellow mirrors are efficient  
reflectors of headlamp glare which itself is yellow.  
Consequently, prolonged exposure to sunlight and UV  
radiation, or reducing UV degradation in electro-optic  
20 mirrors with UV absorbing additives, can create negative  
consumer reaction and acceptance. Likewise, a yellow tint  
in, for example, an automotive sunroof is consumer  
displeasing as it detracts from the consumer's appreciation  
of, and natural view of, the blue sky.

25 Another objective in the use of rearview mirrors  
is the matching of human sight sensitivity in various light  
conditions during the use of such mirrors to the glare  
sources and ambient lighting present. It is known that the  
spectral sensitivity of the human eye depends on its light  
30 adaptation. Thus, daylight and night driving conditions  
create differing human eye sensitivities. Further, nearly

1 all night driving is affected by the reflection of light  
from the headlights of the driver's own vehicle on the road.  
The electro-optic mirror assemblies of this invention  
should, therefore, optimally be constructed to correspond as  
5 much as possible with the eye sensitivities in both day and  
night driving conditions.

The electro-optic media commonly used in  
electro-optic mirrors and windows are often constituted of  
materials and chemicals of a potential toxic or otherwise  
10 hazardous nature. Should the mirror glass break in an  
accident, there is a possibility of automobile occupants  
contacting the electro-optic media, either directly or by  
contact with glass particles to which these potentially  
hazardous media are still adhering. Such contact presents a  
15 hazard to the occupants through toxic effects, and through  
skin irritation such as to eyes and facial areas. The  
anti-lacerative layers and laminate interlayers of this  
invention offer a barrier that ensures that contact with  
chemicals used within the mirror is minimized should the  
20 glass shatter in an accident.

Yet another problem is unwanted misting or fogging  
of the rearview mirror surface or the glazing surface when  
the vehicle encounters high humidity conditions. For  
example, in damp, cold conditions where the interior  
25 passenger compartment of a vehicle has a highly humid  
atmosphere, water droplets may tend to condense on the  
rearview mirror surface or window surface thereby obscuring  
vision in the mirror or through the window. Not only does  
such condensation prevent effective use of the mirror or  
30 window, but also requires frequent wiping by the vehicle  
driver which distracts his attention from driving.

1                   Vehicular windows provide a field of view so that  
the driver can make safe driving decisions and allow  
occupants to comfortably view the surroundings. Glass  
vehicular sunroofs are luxury items that serve both  
5                   aesthetic and functional needs. A transparent sunroof is  
primarily consumer-selected so that the occupants feel less  
claustrophobic and more linked to the outside environment.  
Sunroofs have a functional benefit in that, when opened,  
they can greatly increase cabin ventilation and so  
10                  substitute somewhat for air-conditioning.

                  As reviewed in the publication SMART WINDOWS FOR  
AUTOMOBILES by Niall R. Lynam, SAE paper #900419, Society of  
Automotive Engineers, International Congress and Exposition,  
Detroit, Michigan, February 16 - March 2, 1990, the  
15                  disclosure of which is hereby incorporated by reference,  
increases in the area of windows used in automobiles coupled  
with down-sizing of vehicular air-conditioners and  
environmental concerns associated with use of halocarbons in  
air-conditioners, have led to an increased need to use solar  
20                  heat-load reducing glazing in vehicles. Since solar energy  
(for solar mass 2) is, on the average, 3% ultraviolet (UV),  
48% visible radiation, and 49% near-infrared (NIR)  
radiation, nearly one-half of the solar energy can be  
eliminated without any loss in visibility.

25                  Solar-energy reducing glazing is already in use on  
automobile windows and is based on two principles:  
modification of the glass composition to increase the  
infrared absorption; and deposition of single and multilayer  
coatings to reflect or absorb infrared radiation. In a  
30                  vehicle, the glazing need not be concerned with heat  
insulative properties such as are required for solar

1 efficient windows in buildings and homes. Building solar  
windows allow as much of the solar spectrum as is possible  
to transmit into the room but also trap this solar energy by  
acting as a heat mirror for energy radiated from walls,  
5 floors, furniture, etc.

With respect to a vehicle, heat built up when  
parked or driven in sunny climates is the principal concern.  
Thus, the solar glazing used in vehicles should, ideally,  
reflect away all of the incident near-IR solar radiation  
10 above around 800 nm since visible light is between about 400  
and 800 nm. Even with such reflection, however, the  
approximate 50% of solar energy contained in the UV/visible  
spectral region, if transmitted, can contribute to heat  
buildup within the vehicular cabin.

15 Chromogenic materials have been suggested for  
providing electrically variable control over solar  
transmission in automobile windows. SAE paper #900419  
discloses a variety of possible designs and constructions,  
among them being designs using liquid crystal or  
20 electrochromic materials. Liquid crystal designs, and  
particularly those that operate by scattering light rather  
than by absorbing/reflecting light, however, yield only  
moderate solar energy benefit when used in automobile  
glazing. Electrochromic windows, because they do not  
25 operate by a light scattering mechanism, are preferred for  
use in variable transmission solar-efficient automobile  
window glazing.

A wide variety of infrared attenuating means  
including those that operate principally by reflecting  
30 varying amounts of the near-IR region, or by absorption,  
also have been disclosed in the prior art. Some have been

1 used in association with variable transmission liquid  
crystal panels. For example, U.S. 4,749,261 to McLaughlin  
et al. describes a liquid crystal material operable to  
modulate light transmitted through a panel such as a  
5 sunroof, window, or partition. The liquid crystal material  
selectively operates to transmit or to scatter light.

McLaughlin et al. describe an embodiment which  
includes an infrared light reflective material which may  
take the form of a stainless steel or tin oxide, optically  
10 transparent, infrared reflecting, and electrically  
conductive coating that preferentially reflects infrared  
light while allowing visible radiation to pass. McLaughlin  
et al., however, fail to explicitly distinguish to which  
portion of the infrared spectrum (i.e., near-IR between 800  
15 nm and 2500 nm or IR above 2500 nm) their invention is  
directed, and fail to combine that revelation with an  
electrochromic medium. Other references have failed to  
distinguish the particular needs of vehicular variable  
transmission glazing from variable transmission glazing  
20 usable as building windows and the like.

Accordingly, a need is apparent for a laminate  
electro-optic vehicular rearview mirror and glazing assembly  
which can be effectively scatterproofed to retain glass  
fragments from both glass pieces in the assembly, protected  
25 against lacerative-type injuries, protected against  
ultraviolet radiation damage throughout its life, and  
protected against annoying fogging and misting of the  
interior cabin surface in high humidity conditions. In  
addition, there is a related need for electro-optic rearview  
30 mirror assemblies which provide reflected light of a  
commercially and consumer acceptable color or tint and which



1 match human sight sensitivity in both day and night  
conditions to the glare sources and ambient lighting  
present.

5 In addition, a further need is apparent for a  
combination near-infrared attenuating/electrochromic window  
which maximizes solar attenuation performance while allowing  
maximum variability of visible light. There is also a  
related need for a vehicular window which combines an  
10 electrochromic medium which attenuates visible light by  
absorbance and/or reflection with an efficient near-infrared  
reflector and an ultraviolet reducing means. Further, there  
is a related need for a solar attenuating window which can  
be effectively scatterproofed to retain glass fragments from  
the glass pieces in the window, protected against  
15 lacerative-type injuries, protected against leakage of  
chemicals, protected against ultraviolet radiation damage  
throughout its life, and protected against annoying fogging  
and misting of its surface in high humidity conditions.

#### SUMMARY OF THE INVENTION

20 The present invention overcomes the above problems  
by providing a laminate electro-optic vehicular rearview  
mirror which is protected against scattering of glass or  
other mirror element fragments if broken or damaged in a  
collision while reducing the risk of laceration from contact  
25 with the front glass or other element. In addition, the  
assembly is protected against degradation by ultraviolet  
radiation. The ultraviolet radiation reduction may be  
incorporated together with the scatterproofing,  
anti-lacerative protection. Further, the assembly may  
30 incorporate anti-fogging/anti-misting materials which

1 prevent or reduce condensation and fogging in high humidity conditions.

5 In one form, the invention is an anti-lacerative, scatter protected, laminate, electro-optic rearview mirror assembly including first and second spaced optically transparent elements mounted in a mirror case. The elements each have front and rear surfaces defining a space between the rear surface of the first element and the front surface of the second element. An electro-optic medium is included 10 in the space and has a light transmittance variable upon application of an electric field. Means are provided for applying an electric field to the electro-optic medium to cause variation in the light transmittance thereof. A reflective coating is included on one surface of the second 15 element and is adapted to reflect light incident thereon through the first element and the electro-optic medium. A layer of optically transparent, tear/perforation resistant material is adhered to the front surface of the first element for retaining and preventing scattering of fragments from that element in the event of damage or breakage and for 20 reducing risk of laceration from contact with the first element if damaged or broken.

25 The optical elements may be glass or plastic. The anti-lacerative, anti-scattering layer preferably is a sheet of polymer material such as reticulated polyurethane. In order to reduce ultraviolet radiation transmitted into the assembly, the polymer may be a combination of polyvinylbutyral and polyester which has ultraviolet radiation reducing properties. Alternately, the 30 anti-lacerative layer may incorporate ultraviolet radiation absorbing, blocking or screening additives selected from the

1 group including benzophenones, cinnamic acid derivatives,  
esters of benzoin acids, salicylic acid, terephthalic and  
isophthalic acids with resorcinol and phenols, pentamethyl  
piperidine derivatives, salicylates, benzotriazoles,  
5 cyanoacrylates, benzilidenes, malonates and oxalanilides  
which may also be combined with nickel chelates and hindered  
amines. These additives also stabilize the anti-lacerative  
layer itself against ultraviolet degradation.

Another UV radiation reducing alternative is the  
10 use of a clear, transparent UV transmission reducing coating  
preferably applied to the front surface of the front glass  
element followed by the anti-lacerative, scatterproofing  
polymer layer.

It is also possible to incorporate a sheet  
15 polarizer with the anti-lacerative layer, or apply a  
dichroic, reflective filter material to the glass element  
which provides wide band ultraviolet radiation reduction.  
Examples of such filters include thin film stacks.

It is also possible to substitute a laminated  
20 glass assembly for the front element, such assembly  
including a pair of glass panels adhered to one another with  
a sheet of polyvinylbutyral or sheet polarizer which have  
ultraviolet radiation reducing qualities. An  
anti-lacerative layer may be applied to the front surface of  
25 the first of the two glass panels in such a laminate.

A second form of the invention is a reduced  
ultraviolet radiation transmitting laminate electro-optic  
rearview mirror assembly which also includes first and  
second spaced optically transparent elements, an  
30 electro-optic medium therebetween, means for applying an  
electric field to the electro-optic medium and a reflective

1 coating on one surface of the second element. In this form,  
ultraviolet radiation reducing means are incorporated in the  
assembly for reducing transmission of ultraviolet radiation  
into the electro-optic medium and the assembly.

5 Preferably, such ultraviolet radiation reducing  
means may include glass having an increased iron oxide or  
cerium oxide content or other specialized glasses such as  
blue or green tinted glass which are highly transmitting in  
the visible portion of the electromagnetic spectrum but have  
10 greatly reduced transmission in the ultraviolet portion of  
the electromagnetic spectrum. Anti-lacerative layers may be  
adhered to the front surface of such UV reducing glass to  
both strengthen the glass and provide anti-lacerative,  
scatterproofing properties. When such anti-lacerative  
15 layers are used, similar UV absorbers, blockers and  
screening materials may be incorporated in such layer.  
Alternately, sheet polarizers, transparent, UV reducing  
coatings, and UV radiation dichroic reflective filter  
materials may be used or added. Anti-fogging additives may  
20 also be included.

In addition, the ultraviolet radiation reducing  
means may include a laminated assembly incorporated as the  
front or first element of the mirror assembly and include  
spectrally selective absorbing means for absorbing more  
25 light in those regions of the visible spectrum from about  
560 nanometers to about 780 nanometers than is absorbed in  
those regions of the visible spectrum from about 400  
nanometers to about 560 nanometers. Such spectrally  
selective absorbing means may include blue or green tinted  
30 specialized glass or blue or blue/green tinted polymeric  
interlayers adhering the panels of the laminate front

1 element together. In addition, coatings or layers of UV  
radiation reducing paint or lacquer or polymeric films may  
be included on the interior, facing surfaces of the  
laminate. Alternately, the panels of the laminate first  
5 element assembly may be adhered via a moderate to low  
modulus of elasticity adhesive layer which is preferably  
poured between the panels, cured with ultraviolet radiation,  
and which preferably includes an index of refraction similar  
to that of the glass panels to reduce distortion.

10 It is also possible to incorporate UV radiation  
reducing additives directly in the clear plastic when such  
plastic is used to form the first optical element.  
Alternately, UV reducing additives can be added to the  
electro-optic medium for UV stabilization.

15 The present invention also provides a combination  
near-infrared attenuating, electrochromic glazing assembly  
which is protected against scattering of glass or fragments  
if broken or damaged in a collision while reducing the risk  
of laceration from contact. Further, protection is offered  
20 against contact with the chemicals used in the  
electro-optical medium should the assembly be damaged in an  
accident. In addition, the window assembly is protected  
against degradation by ultraviolet radiation. The  
ultraviolet radiation reduction may be incorporated together  
25 with the scatterproofing, anti-lacerative protection.  
Further, the window assembly may incorporate  
anti-fogging/anti-misting materials which prevent or reduce  
condensation and fogging in high humidity conditions.

30 In one form, the invention is an anti-lacerative,  
scatter protected, electrochromic glazing assembly including  
first and second spaced optically transparent elements. The

1 elements each have inside and outside surfaces defining a  
space between the outside surface of the first element and  
the inside surface of the second element. An electrochromic  
medium is included in the space and has a light  
5 transmittance variable upon application of an electric  
field. Means are provided for applying an electric field to  
the electrochromic medium to cause variation in the light  
transmittance thereof. Near-infrared reflective means are  
located on at least one of the first and second elements for  
10 reducing the transmission of near-infrared radiation through  
said window assembly. The reflective means incorporate at  
least one semi-transparent, elemental, thin metal film which  
reflects at least about 30% of the solar energy for Air Mass  
2 in the spectral region from 800 nanometers to 2500  
15 nanometers. In a preferred embodiment, the thin metal film  
has a physical thickness of between about 80 angstroms and  
300 angstroms and, preferably, of sheet electrical  
resistance of no greater than about 8 ohms/square.

20 The optical elements for the glazing assembly may  
be glass or plastic and may employ the same anti-lacerative,  
anti-scattering, absorbing/filtering, tinting and  
ultraviolet reducing means listed above for the optical  
elements of the electro-optic mirror. It is also possible  
to substitute a laminated glass assembly for the inside  
25 element or the outside element, such assembly including a  
pair of glass panels adhered to one another with an  
interlayer such as a sheet of plasticized polyvinylbutyral  
or equivalent which has ultraviolet radiation reducing  
qualities. An anti-lacerative layer may be applied to the  
30 inner surface of the first or innermost of the two glass  
panels where the first element is such a laminate.

1 In preferred forms, the near-infrared reflective  
elemental thin film is sandwiched between optically  
transparent layers consisting of metal oxide, nitride,  
halide, or sulfide thin films. These thin films serve as an  
5 undercoat to the thin metal film to enhance its bonding to  
the substrate and as a visible light anti-reflection  
overcoat to enhance visible light transmittivity. The  
elemental thin metal film is preferably elemental silver or  
a silver alloy such as with copper but with the silver being  
10 the majority component. Gold, copper, or aluminum are  
alternate choices.

Accordingly, the present invention recognizes and  
applies novel protective concepts to laminate, electro-optic  
vehicular rearview mirrors and glazings not previously  
15 obtained. The invention solves three difficult problems  
encountered in prior commercialization of laminate  
electrochromic mirrors, namely, scatter protecting the front  
glass element, reducing lifetime ultraviolet degradation  
problems arising from the UV instability of the typical  
20 electro-optical medium sealed between the glass elements,  
and reducing fogging or misting caused by condensation in  
high humidity conditions. Further, the invention enhances  
the aesthetic appearance and customer acceptance of UV  
stabilized, electro-optic rearview mirror assemblies which  
25 would otherwise reflect light with a yellow tint by  
absorbing light in the yellow/orange/red regions of the  
visible spectrum to produce a commercially acceptable  
silvery or silvery-blue reflection. Further, the invention  
matches human sight sensitivity in both day and night  
30 conditions for either inside or outside mirrors to the glare  
sources and ambient lighting present by incorporating means

1 causing light reflection in the blue region of the visible  
spectrum and thus well-suited the mesopic human vision  
range. In addition, these results are obtained in an  
economical manner easily incorporated in existing rearview  
5 mirror cases requiring no specialized supports or  
surrounding apparatus in the vehicle.

The present invention also recognizes that maximum  
solar attenuation performance can be obtained through the  
combination of novel near-infrared attenuating concepts and  
10 electrochromic concepts while maintaining maximum  
variability of visible light. The glazing assembly  
incorporating the near-infrared attenuating and  
electrochromic means also incorporates the novel protective  
concepts listed above which solve for glazings or windows  
15 the similar problems encountered in prior commercialization  
of laminate electrochromic mirrors, namely, scatter  
protection, reduction of ultraviolet instability of the  
typical electrochromic medium, and diminution of fogging or  
misting problems. Further, the solutions suggested for  
20 masking the yellow tint caused by ultraviolet reducers are  
applicable to the window assembly.

These and other objects, advantages, purposes and  
features of the invention will become more apparent from a  
study of the following description taken in conjunction with  
25 the drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional side elevation of a scatter  
protected, anti-lacerative, laminate, electro-optic rearview  
mirror assembly of the present invention;

30 Fig. 2 is a sectional side elevation of a scatter  
protected, anti-lacerative and ultraviolet radiation



1 protected, laminate, electro-optic rearview mirror assembly  
of the present invention;

Fig. 3 is a graph showing percent transmission of  
electromagnetic radiation of wavelengths between 230 and 500  
5 nanometers through a two millimeter glass sheet coated with  
indium tin oxide on one surface and having a sheet of  
polyvinylbutyral/polyester composite adhered to its opposite  
surface;

Fig. 4 is a graph of the percent transmission of  
10 electromagnetic radiation of wavelengths between 230 and 500  
nanometers through a two millimeter glass sheet coated only  
on one surface with indium tin oxide;

Fig. 5 is a second embodiment of the scatter  
protected, anti-lacerative and ultraviolet radiation  
15 protected, laminate, electro-optic rearview mirror assembly  
of the present invention;

Fig. 6 is a third embodiment of the scatter  
protected, anti-lacerative and ultraviolet radiation  
protected, laminate, electro-optic rearview mirror assembly  
20 of the present invention;

Fig. 7 is a fourth embodiment of the scatter  
protected, anti-lacerative and ultraviolet radiation  
protected, laminate, electro-optic rearview mirror assembly  
of the present invention;

25 Fig. 8 is an ultraviolet radiation protected,  
laminate, electro-optic rearview mirror assembly of the  
present invention;

Fig. 9 is a second embodiment of an ultraviolet  
radiation protected, laminate, electro-optic rearview mirror  
30 assembly of the present invention;

1 Fig. 10 is a scatter protected, anti-lacerative,  
anti-fogging, laminate, electro-optic rearview mirror  
assembly;

5 Fig. 11 is a graph showing percent transmission of  
electromagnetic radiation through a one millimeter glass  
sheet coated with indium tin oxide on one surface and a  
coating of clear acrylic including CYASORB<sup>TM</sup> UV radiation  
reducing compounds on its opposite surface;

10 Fig. 12 is a graph showing percent transmission of  
electromagnetic radiation through a one millimeter glass  
sheet coated with indium tin oxide on one surface and a  
coating of clear acrylic on its opposite surface;

15 Fig. 13 is a graph showing percent transmission of  
electromagnetic radiation through a one millimeter glass  
sheet coated with indium tin oxide on one surface and clear  
UV protecting lacquer on its opposite surface;

20 Fig. 14 is a fifth embodiment of the scatter  
protected, anti-lacerative and ultraviolet radiation  
protected, laminate, electro-optic rearview mirror assembly  
of the present invention;

Fig. 15 is a third embodiment of an ultraviolet  
radiation protected, laminate, electro-optic rearview mirror  
assembly of the present invention;

25 Fig. 16 is a sixth embodiment of the scatter  
protected, anti-lacerative, ultraviolet radiation protected,  
laminate, electro-optic rearview mirror assembly of the  
present invention;

30 Fig. 17 is a graph showing the solar spectrum in  
the ultraviolet region incident at a desert location such as  
Tucson, Arizona;

1 Figs. 18a and 18b are graphs showing the percent  
light transmission of .063 inch thick, standard, clear, soda  
lime glass in the ultraviolet and visible regions of the  
spectrum, respectively;

5 Fig. 19 is a graph showing the solar radiation in  
the ultraviolet region transmitted by 0.63 inch thick,  
standard, clear, soda lime glass;

Fig. 20 is a graph showing the percent light  
transmission of specific solutions of four cathodic  
10 electrochemichromic compounds including methylviologen (MV),  
ethylviologen (EV), benzylviologen (BV) and heptylviologen  
(HV) in the ultraviolet region of the spectrum;

Fig. 21 is a graph showing the percent light  
transmission of specific solutions of four anodic  
15 electrochemichromic compounds including  
dimethyldihydrophenazine (DMPA), diethyldihydrophenazine  
(DEPA), tetramethylphenylenediamine (TMPD), and  
tetratetramethylbenzidine (TMBZ) as well as thiafulvalene in  
the ultraviolet region of the spectrum;

20 Figs. 22a and 22b are graphs showing the percent  
light transmission of SOLEXTRA 7010<sup>TM</sup> blue tinted  
specialized glass in the ultraviolet and visible regions of  
the spectrum, respectively;

25 Figs. 23a and 23b are graphs showing the percent  
light transmission of SUNGLAS<sup>TM</sup> Blue blue tinted specialized  
glass in the ultraviolet and visible regions of the  
spectrum, respectively;

30 Fig. 24 is a graph showing the relative spectral  
power of Standard Illuminant Sources A and C as well as the  
main color bands of the visible spectrum;

1                    Fig. 25 is a graph showing the dark/scotopic and  
bright/photopic sensitivity of the human eye superimposed on  
the spectral output of a tungsten lamp used as Standard  
Illuminant A;

5                    Figs. 26a and 26b are graphs showing the percent  
light transmission of SUNGLAS<sup>TM</sup> Green green tinted  
specialized glass in the ultraviolet and visible regions of  
the spectrum, respectively;

10                   Figs. 27a and 27b are graphs showing the percent  
light transmission of a pair of clear soda lime glass panels  
laminated together by SAFLEX<sup>TM</sup> SR#11 polyvinylbutyral  
sheeting in the ultraviolet and visible regions of the  
spectrum, respectively;

15                   Figs. 28a and 28b are graphs showing the percent  
light transmission of BUTACITE<sup>TM</sup> Cobalt Blue polymeric  
interlayer sheeting laminated between two clear soda lime  
glass panels in the ultraviolet and visible regions of the  
spectrum, respectively;

20                   Figs. 29a and 29b are graphs showing the percent  
light transmission of a pair of clear soda lime glass panels  
laminated by SAFLEX<sup>TM</sup> Blue Green 377300 polyvinylbutyral  
sheeting in the ultraviolet and visible regions of the  
spectrum, respectively;

25                   Fig. 30 shows the percent light transmission of  
conventional clear soda lime glass coated with UV absorbing  
PC-60 lacquer;

30                   Fig. 31 is a graph showing the percent light  
transmission of clear soda lime glass having a UV absorbing  
coating of ZLI-2456 lacquer;

1                   Fig. 32 is a graph showing the percent light  
transmission of clear soda lime glass coated with a sheet of  
SCOTCHTINT<sup>TM</sup> SH2CLX clear polymeric film;

5                   Fig. 33 is a graph showing the percent light  
transmission of a 35 micron thickness coating of NORLAND NOA  
65<sup>TM</sup> ultraviolet cured epoxy adhesive on clear soda lime  
glass;

10                  Fig. 34 is a graph showing the percent light  
transmission of a 500 microns thick coating of a cured  
mixture of 15% EPON 828<sup>TM</sup>, 35% HELOXY MK107<sup>TM</sup> and 50%  
CAPCURE 3-800<sup>TM</sup> on clear soda lime glass;

15                  Figs. 35a and 35b are graphs showing the percent  
light transmission of a pair of clear soda lime glass panels  
laminated together by BUTACITE<sup>TM</sup> 14 NC-10 polyvinylbutyral  
sheeting in the ultraviolet and visible regions of the  
spectrum, respectively;

20                  Fig. 36 is a graph which illustrates the solar  
energy spectrum (for Air Mass 2) constituting the solar load  
incident on an automobile;

25                  Fig. 36a is a graph which illustrates the variance  
of percent luminous transmission caused by varying the  
thickness of a silver elemental thin film deposited onto a  
soda lime glass substrate;

30                  Fig. 36b is a graph which illustrates that the  
thickness of a silver elemental thin film can be increased  
to 300 angstroms while sustaining the percent luminous  
transmission above 50%;

35                  Fig. 37 is a sectional view of a first embodiment  
of the scatter protected, anti-lacerative, ultraviolet  
radiation protected, laminate, electrochromic, near-infrared  
attenuated glazing assembly of the present invention;

1                    Fig. 38 is a sectional view of a preferred thin  
film stack typically applied to a glass surface of one of  
the glass elements of the present invention to form a  
specialized near-infrared reflector;

5                    Fig. 39 is an enlarged sectional view of the  
near-infrared reflector of the present invention applied to  
a surface of a glass element;

                  Fig. 40 is a sectional view of a second embodiment  
of the scatter protected, anti-lacerative, ultraviolet  
10 radiation protected, laminate, electrochromic, near-infrared  
attenuated glazing assembly of the present invention;

                  Fig. 41 is a graph which compares the  
near-infrared reflectance performance in the 800-2500 nm  
electromagnetic radiation region of the spectrum for a  
15 half-wave coating of ITO on glass, a full-wave coating of  
ITO on glass, and two different, commercially available heat  
mirror structures on glass;

                  Fig. 41A is a graph of the percent reflectance of  
near-infrared solar energy for Air Mass 2 in the 800 to 2500  
20 nanometer spectral range for silver thin elemental films of  
thickness between about 60 and 400 angstroms on glass;

                  Fig. 41B is a graph similar to Fig. 41B but with  
the silver elemental thin film sandwiched between two 180  
angstrom thick titanium dioxide layers on glass;

25                    Fig. 42 is a sectional view of a third embodiment  
of the scatter protected, anti-lacerative, ultraviolet  
radiation protected, laminate, electrochromic, near-infrared  
attenuated glazing assembly of the present invention; and

                  Fig. 43 is a sectional view of perimetral coatings  
30 which can be applied to the scatter protected,  
anti-lacerative, ultraviolet radiation protected, laminate,

1 electrochromic, near-infrared attenuated glazing assemblies  
of the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

### ELECTRO-OPTIC REARVIEW MIRROR DEVICES

5 Referring now to the drawings in greater detail,  
Fig. 1 illustrates a laminate, electro-optic rearview mirror  
assembly 10 having a front element 12 which is scatter and  
anti-lacerative protected with a resinous, polymeric or  
other coated or applied layer 14 on its first or front  
10 surface 11. Element 12 is preferably formed from a  
generally planar sheet of conventional soda lime window  
glass as is second glass element 16 which is spaced slightly  
rearwardly from front glass piece 12 to define a gap or  
space 18 for receiving an electro-optic medium 20 as  
15 explained below. As explained hereinafter, elements 12, 16  
may also be resinous, polymeric sheets to further prevent  
fragment scattering and lacerative injuries if broken and to  
reduce weight. Space 18 is formed between the generally  
parallel rear surface 13 of front glass element 12 and  
20 forward facing surface 17 of rear glass element 16.  
Preferably, each of the front and rear surfaces 13, 17 is  
coated with a layer of indium tin oxide (ITO) which is  
substantially transparent to incident visible light yet is  
sufficiently electrically conductive to enable application  
25 of an electric field or voltage across space 18 between ITO  
layers 13a, 17a. Electrical energy is provided by wire  
leads 22, 24 secured in conventional manner to the upper  
portions of ITO coatings 13a, 17a as shown in Fig. 1.

30 The rear surface 25 of rear glass element 16 is  
coated with a reflective layer 26 preferably of metallic  
material such as aluminum, or a combination of silver and

1 copper as is conventionally known. Such layer provides a  
highly specular surface which reflects approximately 80-90%  
of the light incident thereon through layer 14, front and  
rear glass elements 12, 16 and electro-optic medium 20 in  
5 space 18. In order to prevent scattering of glass fragments  
from the rear glass element 16 in the event of breakage or  
damage during a collision in the vehicle, a layer 28 of tape  
or a plastisol-type plastic adhesive, typically about 0.1  
millimeters thick, is applied to the rear surface of  
10 reflective coating 26. Anti-scattering layer 28 may be  
opaque, translucent or transparent since it is behind  
reflective coating 26 and need not transmit or reflect any  
light.

In order to confine and retain the electro-optic  
15 medium in gap 18, a peripheral seal 29, formed from an epoxy  
material which adheres well to the ITO coatings 13a, 17a on  
glass surfaces 13, 17 is applied adjacent the periphery of  
glass elements 12, 16. A suitable epoxy sealing material is  
EPON 828<sup>TM</sup> from Shell Chemical Company of Houston, Texas  
20 cured by polyamide based curing agents such as V-40<sup>TM</sup> from  
Miller Stephenson Company of Danbury, Connecticut. The  
epoxy is preferably silk screened onto the inner surface of  
the front glass element 12 or the back glass element 16 or  
onto both glass elements. The corresponding glass element  
25 is then placed face to face with the still tacky epoxy.  
Seal 29 is then fully cured, typically by placing the  
assembly into an oven at 110° C. for three hours. Gap 18  
can then be filled by a variety of means such as simple  
injection of electro-optically active material using a  
30 syringe or by vacuum backfilling using a technique well  
established for manufacture of liquid crystal devices.



1 Assembly 10 is preferably incorporated in a molded  
thermoplastic or other mirror case 30 of conventional form  
and supported within a vehicle in a conventionally known  
manner through an articulated support from the inside  
5 windshield surface or a header mounted support arm.

Typically, glass elements 12, 16 will each be two  
millimeters in thickness while ITO coatings 13a, 17a will  
have a typical thickness of 1,500 angstroms. Reflective  
coating 26 may have a thickness within the range of between  
10 about 500 and 1,000 angstroms. Various types of  
electro-optic media may be inserted in gap 18. For example,  
a suitable liquid crystal material in which molecules are  
oriented to block the passage of light therethrough when an  
electric field is applied is a guest host dye such as D5<sup>TM</sup>  
15 produced by BDH Co. of Dorset, England dissolved in n-type  
nematic liquid crystal such as  
n-(p-methoxybenzilidene)-p'-butylaniline. For such  
material, cell gap 18 is typically 8 to 12 microns. For  
electrochromic mirrors, the gap may contain a liquid,  
20 thickened liquid, gel or semi-solid material such as  
formulations described in U.S. Patent No. 3,806,229 to  
Schoot. In electrochromic mirrors, a material such as  
POLY-AMPS<sup>TM</sup> available from Lubrizol Corp. of Wickliffe, Ohio  
may be used. Also, a liquid, thickened liquid, gel or  
25 semi-solid material may be used as is conventionally known.  
Cell gap or space 18 is typically 50 to 100 microns in these  
electrochromic or electrochemichromic devices. With the  
latter materials, application of an electric field will  
cause the media 20 to color to successively darker colors or  
30 shades as larger voltages are applied. When voltage is  
turned off or reversed, the coloring is bleached allowing

1 full transmittance of light and, hence, full reflectivity  
from reflective layer 26.

Because the electro-optic media 20 such as those  
described above are typically of relatively low viscosity  
and have little or no capability of retaining or holding  
solid elements thereto, the scatter and anti-lacerative  
protection conventionally available through the use of tape  
or plastisol layers such as those at 28 on rear glass  
element 16 has been unavailable for use with the front glass  
element 12 because transmission of light through the glass  
element must be unimpeded. The present invention overcomes  
that problem by providing scatterproofing, anti-lacerative  
layer 14 which retains fragments should glass element 12 be  
shattered. Layer 14 also provides enhanced anti-lacerative  
protection since it remains intact upon collision, is tear  
and perforation resistant and thus reduces or avoids  
laceration injury to the skin of any person contacting the  
shattered or broken mirror.

A specific example of a material found useful for  
layer 14 is reticulated polyurethane having a thickness  
within the range of about 0.01 to about 0.25 inches and  
marketed under the trade name SECURIFLEX<sup>TM</sup> by Saint-Gobain  
Vitrage of Paris, France. When used as layer 14,  
SECURIFLEX<sup>TM</sup> has excellent adhesion to glass surface 11 for  
retaining glass fragments during and after shattering in a  
collision. It also has high deformation capacity to resist  
tearing while continuing to form a protective screen which  
protects the skin of any person impacting the mirror and  
preventing contact with broken, jagged edges of the glass.  
It also has excellent optical quality, clarity and  
transparency so as not to detract from the rear vision

1 capability of the rearview mirror. Further, it is abrasion  
and scratch resistant so that high quality clear images can  
be obtained in the mirror throughout its life. It is also  
relatively inert and resistant to environmental variation  
5 such as high and low temperatures, high and low humidity  
conditions.

Use of an anti-lacerative layer 14 also affords  
another advantage. It is known that several electro-optic  
mirror devices developed in recent years have generally poor  
10 ultraviolet radiation stability. When exposed to prolonged  
ultraviolet radiation from sunlight, such electro-optic  
assemblies may suffer substantial degradation of their  
electro-optic media resulting in poor electrical coloration  
responsiveness including increased response time and/or  
15 failure to properly bleach when electric voltage is switched  
off. Permanent discoloration of the medium may also occur.  
This can cause substantial vision problems. An example of  
the ultraviolet region of the solar spectrum incident at a  
desert location such as Tucson, Arizona is shown in Fig. 17.  
20 Such solar spectrum must typically pass through a glass  
front panel of an electro-optic rearview mirror assembly to  
irradiate the electro-optic solution in an electro-optic  
rearview mirror assembly such as that shown in Fig. 1 or the  
other assemblies shown herein. Fig. 17 shows that there is  
25 little or no incoming solar radiation below about 295 nm.  
The light transmission of a 1.6 mm thick panel of standard,  
clear, soda lime glass is shown in Figs. 18a and 18b while  
the solar energy spectrum transmitted into any electro-optic  
medium behind such a front glass piece is the combination of  
30 the graphs in Figs. 17 and 18 as shown in Fig. 19. The  
0.063 inch (1.6 mm) soda lime glass panel passes about 63%

1 of the incoming UV solar energy in the 250-350 nm region and  
about 90% in the 350-400 nm region. Overall, a 1.6 mm soda  
lime glass sheet passes about 83% of the incident solar  
energy in the 250-400 nm region. Thus, a substantial  
5 portion of the incoming solar UV radiation is unattenuated  
by the glass front panel.

When such solar radiation passes into the  
electro-optic medium therebehind it irradiates the  
electro-optic species. Electrochromic (ECC) materials,  
10 especially organic species, are particularly susceptible to  
degradation by UV radiation. This is caused by their  
absorption of UV radiation with consequent disruption of  
electronic states. As shown in the graph of Fig. 20, the  
cathodically coloring ECC species most commonly used in  
15 prior art literature such as methylviologen (MV),  
ethylviologen (EV), benzylviologen (BV), and heptylviologen  
(HV), have an absorption peak below 295 nm and, thus, are  
largely nonabsorbing to the solar UV radiation transmitted  
into an ECC cell. However, as shown in Fig. 21, anodic  
20 compounds, such as dimethyldihydrophenazine (DMPA),  
diethyldihydrophenazine (DEPA), tetramethylphenylenediamine  
(TMPD), and tetratetramethylbenzidine (TMBZ) as well as  
thiafulvalene have substantial UV radiation absorbance in  
the 250-400 nm region. For example, DMPA in 0.0002M  
25 solution in acetonitrile (AN) and in a 1 mm pathlength  
quartz cell absorbs about 22% of the UV solar energy  
spectrum in the 250-350 nm region. Therefore, it is  
desirable to shield the ECC compounds from UV irradiation in  
this region. Also, because some absorption continues up to  
30 about 400 nm or so, and since the solar energy transmitted  
into the cell as shown in Fig. 19 is also substantial in the

1 350-400 nm region, it is beneficial to protect the ECC  
compounds from irradiation in this region as well.

5 The present invention recognizes that use of  
ultraviolet radiation absorbing, blocking or screening  
materials, either incorporated in the anti-lacerative layer  
or in layers in addition to such layer, will reduce  
ultraviolet radiation impinging on the mirror assembly and  
the electro-optic medium and significantly prolong its  
lifetime.

10 It is also recognized that substantial reduction  
in the amount of UV radiation transmitted into the  
electro-optic medium of the assembly may be accomplished by  
using specialized glasses, paints/lacquers, and laminate  
interlayers, coatings and/or films while simultaneously and  
15 synergistically protecting a vehicle driver against  
laceration or injury due to scattering or breaking of glass  
fragments should the protected mirror assembly be struck in  
an accident.

20 As shown in Fig. 2, an enhanced, laminate,  
electro-optic rearview mirror assembly 35 with increased  
ultraviolet radiation resistance and stabilization is shown.  
As with subsequent embodiments of the invention explained  
below, assembly 35 is similar to the mirror assembly 10 of  
Fig. 1 but includes a different scatter protecting,  
25 anti-lacerative, UV radiation reducing layer 36 on the front  
surface of glass element 12. Layer 36 is preferably of  
two-ply construction comprising a laminate of  
polyvinylbutyral and polyester commercially available from  
E. I. duPont de Nemours and Company under Product No. duPont  
30 BE1028D and also has the same qualities as described for  
polyurethane layer 14. The outer ply or layer 40 is

1 abrasion resistant, weather resistant, polyester while the  
inner ply or layer 38 is resilient, tear resistant  
polyvinylbutyral. Composite layer 36 has a thickness  
preferably between about 0.005 and 0.25 inches, and provides  
5 a solution to two problems found during commercialization of  
prior known laminate electro-optic, and especially  
electrochromic mirrors, i.e., difficulty in scatter  
protecting the front glass element 12 and protection against  
degradation of the electro-optic or electrochromic media 20  
10 in space 18 throughout the lifetime of the assembly due to  
inherent ultraviolet radiation instability and sensitivity.

The polyester/polyvinylbutyral composite layer 36  
is a particularly good filter for ultraviolet radiation as  
shown in Figs. 3 and 4. Fig. 3 is a graph of the percent  
15 transmission of electromagnetic radiation through a two  
millimeter thick element of conventional soda lime window  
glass coated with a layer of indium tin oxide (ITO) on one  
surface and a layer of duPont BE1028D polyvinylbutyral/  
polyester composite on the opposite surface. The graph  
20 shows the transmission over the wavelength spectrum between  
230 and 500 nanometers (nm) and illustrates that below about  
350-360 nm, wavelength transmission is cut off or stopped.  
Ultraviolet radiation which penetrates the earth's  
atmosphere from the sun typically ranges in wavelength over  
25 a wide band of between about 290 and 400 nanometers (nm).  
In contrast, light sensitive to the human eye ranges from  
about 400 nm to about 700 nm. Hence, the composite  
polyvinylbutyral/polyester layer 36 substantially eliminates  
ultraviolet radiation below about 350 nm while  
30 simultaneously scatter protecting and protecting against  
laceration when applied to the mirror glass surface.

1 Compare the graph in Fig. 3 to that in Fig. 4  
which illustrates a two millimeter glass element coated only  
on one surface with indium tin oxide and not including a  
polyvinylbutyral/polyester layer. Such ITO coated glass  
5 transmits light in the visible wavelength spectrum above  
about 400 nanometers but also allows transmission of  
ultraviolet wavelengths down to about 295 nm which is  
substantially farther into the UV region than with the  
coated glass having the two-ply composite layer 36 thereon  
10 as shown in Fig. 3. Hence, reduction of UV radiation  
intensity passing through front glass 12 of such laminate  
mirrors as in assembly 35 substantially increases the useful  
lifetime of the mirror assembly.

15 A specific example of an assembly such as that  
shown at 35 comprising a laminate electrochromic mirror and  
providing the anti-lacerative, anti-scatter, UV radiation  
reducing advantages of the present invention was fabricated  
consisting of two plates of ITO coated, conventional soda  
lime window glass separated by a gap of 50 microns. The  
20 space between the two glass elements was filled with an  
electrochromic solution consisting of N,N,N',N'  
tetramethyl-1,4-phenylenediamine 0.025M,  
1,1'-diheptyl-4,4'-bipyridinium dibromide 0.025M and  
tetrabutylammonium fluoroborate 0.5M dissolved in propylene  
25 carbonate. The nonmirrored front glass piece was  
anti-lacerative protected with a duPont BE1028D two-ply,  
anti-lacerative layer consisting of an outer abrasion  
resistant layer of polyester and an inner layer of  
polyvinylbutyral as described above in connection with Fig.  
30 2. Reflective coated, rear glass plate 16 was scatter  
protected on its rear surface using conventional tape. The

1 assembly was shattered by dropping a one kg weight over a  
distance of one meter to impinge on the front nonmirrored  
glass element, the anti-lacerative layer retained glass  
fragments from the front glass and remained unperforated  
5 such that it would have provided anti-lacerative protection  
if struck by a person in an accident. Moreover, when this  
laminate electrochromic mirror assembly was placed under UV  
lamps in a sunlight simulator, electrochromic activity and  
general mirror performance was maintained for a period of  
10 some five (5) times longer than that obtained using a  
control sample which was similarly tested with UV radiation  
but was not anti-laceratively protected with a  
polyester/polyvinylbutyral layer.

15 Although the anti-scattering, anti-lacerative  
layer 14 of assembly 10 in Fig. 1 provides some ultraviolet  
radiation reduction protection, and is itself ultraviolet  
radiation stable, the polyvinylbutyral/polyester composite  
is preferred since the polyvinylbutyral ply or layer has  
significantly higher UV radiation reduction capability as  
20 well as inherent UV stability than does polyurethane.

Longer lifetimes for laminate electro-optic  
rearview mirror assemblies can be achieved by using  
ultraviolet radiation absorbing, blocking or screening  
materials added to or incorporated with the anti-scatter,  
25 anti-lacerative layers 14, 36 as shown in Figs. 1 and 2.  
Most commercial polymers absorb ultraviolet radiation  
because they possess chromophoric groups either as regular  
constituents or as impurities. Only those chromophores  
which absorb electromagnetic radiation of a wavelength below  
30 about 400 nanometers are, therefore, effective screens  
against UV radiation. Polycarbonate, polyester and aromatic



polyurethanes contain such chromophores as a major part of their structures. However, polyolefins contain only relatively insignificant amounts of these chromophores as impurities. Yet, these above materials do not absorb UV radiation uniformly over the entire UV range. The chromophores which do absorb UV radiation can be conjugated structures, carbonyl groups, aromatic repeat units and heterocyclic repeat units. In addition, if polymers are used as UV screeners, they themselves must be stabilized against UV radiation since UV absorption generates free radicals which lead to chain scission and cross-linking and creation of other structures in these polymers. Thus, UV radiation itself degrades the polymer material which is intended to provide a UV absorber, block or screen by making the polymer brittle and even imparting color in the visible region.

The addition of UV absorbing, blocking or screening additives to polymers such as the polyurethane and/or polyvinylbutyral/polyester composite layers 14, 36 makes these materials more efficient UV screeners and preserves their properties over a longer period of time. Such UV additives, known as stabilizers, are transparent in the visible region and work to absorb UV radiation, quench the free radicals which are generated in the polymer and prevent oxidation reactions which lead to polymer degradation. For example, UV stabilizing additives drawn from benzophenones, cinnamic acid derivatives, esters of benzoin acids, salicylic acid, terephthalic and isophthalic acids with resorcinol and phenols, pentamethyl piperidine derivatives, salicylates, benzotriazoles, cyanoacrylates, benzilidenes, malonates and oxalanilides are effective to

block UV radiation and stabilize the polymer layer when impregnated in such layer, included in separate coatings in addition to such layer or incorporated directly in front element 12 such as when it is cast from plastic. Other additives may be combined with the above materials such as nickel chelates and/or hindered amines. The following table shows several combinations of commercially available polymers and UV additives which may be used:

<u>Polymer</u>	<u>Stabilizer</u>
Polyolefins	2-hydroxy-4-octoxybenzophenones nickel chelates hindered amines
Styrenics	hindered amines 2-hydroxyphenylbenzotriazole
PVC	benzotriazoles benzophenones acrylonitriles
Unsaturated Polyesters	2-hydroxybenzotriazole benzophenone
Polyurethanes	benzotriazole pentamethyl piperidine derivatives
Polycarbonate	2-hydroxy-phenylbenzotriazole
Polyamides	tetramethyl piperidyl sebacate
Acrylic	2-hydroxyphenylbenzotriazole

In many instances, two or more of such additives are combined together for increased, synergistic effects in UV radiation reduction and stabilization.

UV stabilizers/blockers/filters/absorbers are incorporated directly into the polymer anti-lacerative layer(s) 14, 36 in a variety of ways. For polyvinylbutyral, UV blocking additives are compounded with the PVB resin. Alternately, the UV blockers are dissolved in plasticizers which are then used to plasticize the PVB. PVB can also be

1 dissolved in a suitable solvent, with UV stabilizers next  
added to the PVB solution and a UV stabilized PVB film/sheet  
can be cast from this solution. UV blockers can also be  
5 incorporated into polyester either through compounding or by  
solvent casting. Polyurethane anti-lacerative sheeting is a  
thermoset usually formed from reaction of isocyanate and  
polyols. Since both of these starting materials are  
liquids, UV blockers/stabilizers/filters/absorbers can be  
10 added to either the isocyanate component or the polyol  
component or to both. Concentrations of the various  
additives for combination with the various polymers are  
conventionally known such as are disclosed in U.S. Patent  
No. 4,657,796 to Musil et al.

15 As an alternative, UV blockers, filters or  
screens, or absorbers may be coated directly onto the front  
element 12, preferably on the first surface 11, regardless  
of whether it is glass or plastic (see Fig. 9). A clear  
transparent coating packed with UV blockers/filters/  
20 absorbers may be cast, spun, dipped, brushed, painted or  
sprayed onto glass surfaces through which UV radiation must  
pass before reaching the electro-optically active medium. A  
suitable solution can be made by dissolving a clear  
thermoplastic acrylic, polystyrene, NAS (70% polystyrene;  
30% acrylic copolymer), polycarbonate, TPX  
25 (polymethylpentene), or SAN (styrene acrylonitrile  
copolymer) in a suitable solvent such as acetone, ethyl  
acetate, acetonitrile, tetrahydrofuran or any other common  
volatile solvent. To this, UV blockers are added such as  
CYASORB<sup>TM</sup> UV1084 or UV5411, available from American Cyanamid  
30 of Stamford, Connecticut, or any suitable material drawn  
from known UV blockers up to concentrations close to their

1 solubility limit. CYASORB<sup>TM</sup> UV5411 is a benzotriazole while  
CYASORB<sup>TM</sup> UV1084 is an organo-nickel complex or nickel  
chelate. The solution so constituted can then be cast,  
5 spun, sprayed, brushed, painted or dipped onto, for  
instance, the outer surface of front glass element 12  
followed by application of anti-lacerative layer 14 or 36  
either with or without UV reducing additives as described  
above.

10 For example, a 2.5% weight/volume casting solution  
was prepared by dissolving commercial acrylic sheeting in a  
50:50 mixture of acetone and toluene. To 100 mls of this  
acrylic solution, 1.6 g of CYASORB<sup>TM</sup> UV1084 and 1.89 g of  
CYASORB<sup>TM</sup> UV5411 were added. When cast onto a piece of one  
15 mm thick ITO coated glass in a thickness of about eight  
microns, the acrylic was UV stabilized and yielded the  
transmission spectrum shown in Fig. 11. Transmission  
through such coated glass in the region from about 280 nm to  
about 350 nm was markedly reduced compared to similar  
transmission spectra generated when only a 2.5% non-UV  
20 stabilized acrylic solution was cast onto ITO coated glass  
(Fig. 12) or when no acrylic was cast and a spectrum of ITO  
coated glass itself was generated (Fig. 4). In spite of low  
UV transmission, the UV stabilized cast acrylic coating was  
highly transparent in the visible portion of the  
25 electromagnetic spectrum.

Alternatively, UV stabilizers/blockers/filters/  
absorbers can be incorporated into the polysiloxane  
solutions, such as Dow Corning ARC<sup>TM</sup> coatings, available  
from Dow Corning Inc. of Midland, Michigan. These are  
30 commonly available to impart a transparent anti-abrasion  
coating onto optical plastics which can be used for front

1 element 12 to further reduce fragment scattering and  
laceration-type injuries. Alternately, UV stabilizers/  
absorbers/blockers/filters can be added to thermosetting  
optical plastics such as CR-39<sup>TM</sup> (allyl diglycol carbonate)  
5 or optical nylons or polysulfones. With thermosetting  
materials such as CR-39<sup>TM</sup> optical plastic, available from  
PPG Industries, Inc. of Pittsburgh, Pennsylvania, the UV  
absorbing, blocking or screening additive is incorporated in  
the initial plastic components and cast onto the front  
10 surface of front element 12 prior to assembly followed by  
suitable curing in the conventionally known manner.

If a UV absorbing/blocking/screening material such  
as CR-39<sup>TM</sup> above is cast as a separate sheet, it may then be  
mounted on and adhered to front surface 11 of a clear  
15 plastic front element 12 with an adhesive bonding substance  
such as VERSILOK<sup>TM</sup> acrylics available from Lord Corporation  
of Erie, Pennsylvania. In such case a UV reducing additive  
such as benzotriazoles or hindered amines can also be  
incorporated directly in the adhesive bonding agent.  
20 Alternately, the sheet may be press laminated to the surface  
under increased pressure and modest heat.

As an alternative to adding the UV reducing  
additive materials to the scatter preventing,  
anti-lacerative layers 14, 36 or other polymers, or as  
25 coatings in combination with such anti-lacerative layers, or  
as coatings in combination with the addition of the above  
mentioned types of additives to such layers, other materials  
may be used to decrease the ultraviolet radiation passing  
through the front element 12 to the interior of the mirror  
30 assemblies as shown in Figs. 5-10.

1 In Fig. 5, where like numerals indicate like parts  
to those described above, a laminate, electro-optic rearview  
mirror assembly 45 has front glass 12 replaced with a  
5 laminate glass assembly comprised of a front glass element  
12a having parallel front and rear surfaces adhered to an  
intermediate glass element 12b also having parallel surfaces  
by an interlayer 12c of polyvinylbutyral (PVB). Layer 12c  
is adhered to the rear surface of glass element 12a and the  
10 front surface of glass element 12b by heat and pressure  
lamination such as with the conventionally known autoclave  
method or the like. Glass elements 12a, 12b may be  
conventional soda lime window glass. The rear surface of  
glass element 12b is coated with indium tin oxide layer 13  
15 which is, in turn, sealed with the front ITO coated surface  
of rear glass element 16 by seal 29 to provide the space 18.  
A scatter preventing, anti-lacerative, ultraviolet radiation  
reducing layer such as that shown above at 14 or 36 may be  
adhered to the front surface of front glass element 12a by  
20 suitable adhesives, heat, pressure or curing to provide the  
additional advantages noted above. However, the laminate  
glass assembly of assembly 45 inherently affords extra  
safety advantages by contributing to the reduction of  
ultraviolet radiation transmission into the assembly and  
25 providing greater shatter resistant strength for the  
assembly while providing scatter protection due to the use  
of the PVB layer 12c together with the anti-lacerative  
protection of layers 14 or 36.

30 With reference to Figs. 6 and 7, where like  
numerals indicate like parts, it is also possible to  
incorporate sheet polarizers in the mirror assembly to  
further prevent ultraviolet radiation transmission into the

1 assembly. In Fig. 6, a laminate electro-optic rearview  
mirror assembly 50 includes a layer of light polarizing  
sheet material 52 applied to the front surface 11 of front  
glass element 12 prior to adherence of the anti-scatter,  
5 anti-lacerative layer 14 or 36 mentioned above. A suitable  
H-sheet polarizer material is that sold under Product No.  
HN-38 by Polaroid Corporation of Cambridge, Massachusetts.  
Such sheet polarizers act to block and screen out  
ultraviolet radiation below wavelengths of about 380 nm.

10 Alternately, a sheet polarizer material 57 like  
that above may be incorporated in the laminate electro-optic  
rearview mirror assembly 55 of Fig. 7 where it is laminated  
and adhered as an interlayer between the front and rear  
surfaces of intermediate and front glass elements 12b' and  
15 12a' to provide a glass laminate assembly. That glass  
assembly is substituted for front glass element 12 just as  
assembly 45 of Fig. 5. As with assembly 45, mirror assembly  
55 has increased mechanical strength due to the laminate  
construction of the front glass panel, may incorporate  
20 scatter preventing, anti-lacerative layers 14 or 36 on the  
front surface of the front glass element 12a' for safety  
purposes, and reduces UV radiation transmitted into the  
assembly due to the UV absorbing and blocking function of  
the sheet polarizer layer 57 and any layer 14 or 36 to  
25 increase the lifetime of the assembly.

In Fig. 8, where like numerals indicate like parts  
to those described above, mirror assembly 60 includes a  
front glass element 62 formed from one of several types of  
specialized glass rather than conventional soda lime window  
30 glass. For example, front glass element 62 may have a  
higher iron oxide content of within the range of about 0.2%

1 to 0.9% by weight thereby increasing the ultraviolet  
radiation absorption, blockage and/or screening effect.  
Similar improvement can be obtained using higher cerium  
oxide content of 0.2% to 0.9% by weight concentration.  
5 Other specialized glasses which have high visible  
transmission but are strong absorbers in the ultraviolet  
electromagnetic region can be used including NOVIOL<sup>TM</sup>  
glasses as described in "Spectral-Transmissive Properties  
and Use of Eye-Protecting Glasses" by R. Stair in National  
10 Bureau of Standards Circular 471 (1948). A two millimeter  
thick sheet of NOVIOL<sup>TM</sup> O CG306 (National Bureau of  
Standards Circular, 471 (1948)) transmits only about 12% of  
the incident ultraviolet radiation at 380 nanometers in  
contrast to transmission of approximately 70% of the  
15 incident ultraviolet radiation at 360 nanometers with a  
conventional soda lime window glass sheet. This is true  
even when such NOVIOL glass is coated with indium tin oxide  
as an electrical conductor. Conventional soda lime glass  
begins to screen out significant amounts of ultraviolet  
20 radiation only below about 300 nm.

Other useful specialty glasses include UV-36<sup>TM</sup>  
glass available from Hoya Corporation of Tokyo, Japan having  
an average transition wavelength of about 360 nm such that  
it cuts off ultraviolet radiation below that wavelength.  
25 Transition wavelength is the wavelength at the midpoint of  
the transition interval where glass goes from being highly  
transmitting to visible radiation to being highly absorbing  
for UV radiation. Other glasses which can be used include  
L-1B<sup>TM</sup> also available from Hoya Corporation having an  
30 average transition wavelength of 420 nm. Other examples  
include CS0501, No. 0-51<sup>TM</sup> available from Corning Glass



1 Works, Corning, New York having a transmittance less than  
0.5% at 334 nm and lower at shorter wavelengths but being  
highly transmitting in the visible electromagnetic region  
and FG-62<sup>TM</sup> available from Ohara Optical Glass Manufacturing  
5 Company, Ltd. of Tokyo, Japan, having a UV cutoff just  
slightly below 400 nm. Such ultraviolet radiation reducing  
glasses may be used either with or without scatter  
preventing, anti-lacerative, UV reducing layers 14 or 36 or  
the UV reducing coatings mentioned above. When used,  
10 however, the scatter preventing, anti-lacerative layers have  
the added advantage of significantly strengthening such  
glass which, in many instances, are mechanically weaker than  
conventional window glass. In addition such speciality  
glasses may be used in the laminate assemblies substituted  
15 for front element 12 as described with Figs. 5 and 7.

As mentioned above, elements 12, 16 may also be  
cut or cast from clear plastic sheet material such as  
acrylic or polycarbonate and used in place of front element  
62 of Fig. 8. Additives such as benzotriazoles and  
20 benzophenones may be incorporated in the plastic to reduce  
UV radiation transmission. Other UV reducing layers or  
coatings as described herein, including polymer layers 14,  
36, may also be used in combination with the plastic  
elements.

25 As shown in Fig. 9, wide band, ultraviolet  
radiation, dielectric, dichroic or reflective filter  
materials may also be used in conjunction with the front  
glass or plastic elements 12 or 62. Suitable dichroic  
filter or reflective materials include thin film coatings 67  
30 which significantly reduce ultraviolet transmission. Thin  
film layers 67 can be applied to any glass or plastic

1 surface ahead of the UV vulnerable electro-optic mirror  
medium 20 but preferably on front or first surface 11. A  
suitable thin film coating is the ultraviolet wide band  
dichroic filter available from Optical Coatings Laboratory,  
5 Inc. of Santa Rosa, California. When applied to the rear  
surface of front element 12 or 62 as shown in Fig. 9 in  
solid lines, coatings 67 are interposed between the element  
rear surface and ITO coating 13a. When applied to the front  
surface 11, however, thin film coatings 67 are interposed  
10 between the front surface and the scatter preventing,  
anti-lacerative layer 14 or 36 as illustrated in phantom.  
Thin film coatings 67 have a transmission of visible light  
over 80% at 550 nm with a sharply lowered transmission of  
about 5% at 400 nm at which level the thin films become  
15 reflecting to UV radiation.

As a substitute for the thin film coatings 67,  
ultraviolet radiation blocking paints or lacquers can be  
applied to the element surfaces provided such paints or  
lacquers are transparent to visible light. A suitable  
20 material for layer 70 is a lacquer supplied as ZLI-2456  
transparent UV protecting lacquer which is a solvent based  
acrylic with added UV stabilizers manufactured by E. M.  
Industries of Hawthorne, New York. Such lacquer  
substantially reduces UV radiation transmitted into the  
25 assembly and is preferably applied to front surface 11 of  
element 12 to avoid dissolving in medium 20.

For example, the above UV protecting lacquer  
ZLI-2456 was coated on a one mm thick sheet of ITO  
conductive glass to a thickness of about 30 microns. The  
30 transmission spectrum of such coated glass is shown in Fig.  
3. It has a sharp transmission cutoff below about 400 nm

1 and greatly reduces UV radiation in the 290-400 nm region as  
compared to that normally transmitted by ITO coated glass  
(see Fig. 4).

5 Thin film coatings or UV reducing paint or lacquer  
layers 67, 70 may be used with conventional soda lime window  
glass as front glass element 12, or with specialized UV  
radiation reducing or higher iron oxide containing glass, or  
other UV reducing elements 62 such as the plastic elements  
mentioned above.

10 As shown in Fig. 10, a further embodiment 75 of  
the laminate electro-optic rearview mirror assembly is  
illustrated including a scatter preventing, anti-lacerative  
layer 77 similar to the polyvinylbutyral/polyester composite  
15 layer 36 described above in connection with Fig. 2 but also  
including silicone moieties chemically incorporated in the  
anti-lacerative composite. Polymer layer 77 including the  
silicone additive prevents condensation and/or beading up of  
condensed water on the coated front surface 11 of front  
20 mirror element 12, 62 in high humidity conditions thereby  
providing an anti-fogging, anti-misting result. A material  
found useful as anti-lacerative, anti-fogging layer 77 is  
silicone impregnated polyurethane supplied under the trade  
name CLARIFLEX<sup>TM</sup> by Saint-Gobain Vitrage of Paris, France.  
25 UV reducing additives such as those described above in  
connection with Fig. 2 may also be incorporated in the  
anti-lacerative, anti-fogging layer to increase the lifetime  
of the assembly. Alternately, front glass element 12, 62  
may be fashioned from conventional soda lime glass, UV  
30 reducing specialized glasses, or polymer plastics. It is  
also possible to utilize thin film coatings or UV reducing  
paints or lacquers 67, 70 on at least one surface of front

1 element 12, 62 when the anti-lacerative, anti-fogging layer  
is incorporated.

It is also possible to incorporate UV radiation  
reducing or absorbing stabilizers directly in the  
5 electro-optic medium 20 injected or otherwise inserted in  
space 18. Such absorbers may be dissolved directly in the  
medium, e.g., an electrochemichromic liquid. The UV  
absorbers are selected to be compatible with the ingredients  
of the medium 20, such that they do not affect the  
10 electrical performance and function of the medium or oxidize  
or reduce in the assembly.

As an example, a laminate electrochemichromic  
mirror was fabricated as described in the above example in  
connection with Fig. 2 except that no anti-lacerative layer  
15 was used over front glass element 12. In addition, UV  
stabilizers CYASORB<sup>TM</sup> UV1084 and CYASORB<sup>TM</sup> UV5411 were added  
to the electrochemichromic active solution prior to filling  
into the gap 20 between front glass 12 and back glass 16.  
Concentration for the UV1084 was 0.6% by volume and the  
20 UV5411 was 0.6% by volume g/cc.

As shown in Fig. 14, where like numerals indicate  
like parts to those described above, another embodiment 85  
of the laminate, electro-optic rearview mirror assembly also  
includes a laminate glass assembly substituted for the front  
25 glass as is the case in embodiments 45 and 55 in Figs. 5 and  
7 above. The front or first, laminate assembly 86 includes  
a front or first glass panel 12d having parallel front and  
rear surfaces adhered to an intermediate glass panel 12e  
also having parallel surfaces by an interlayer 12c of  
30 polyvinylbutyral (PVB) or another interlayer as described  
below. As in the prior embodiments, layer 12c is adhered to

1 the rear surface of glass panel 12d and to the front surface  
of glass panel 12e by heat and pressure lamination such as  
with the conventionally known autoclave method or the like.  
In embodiment 85, however, glass panel 12d is formed from a  
5 blue tinted specialized glass which significantly reduces UV  
radiation transmission while maintaining high visible light  
transmission. The rear surface 13 of glass panel 12e is  
coated with an indium tin oxide layer 13a which is, in turn,  
sealed with the front ITO coated surface 17 of rear glass  
10 element 16 by seal 29 to provide electro-optic media  
receiving space 18 as in the above embodiments.

Preferably, the blue tinted specialized glass 12d  
is formed from SOLEXTRA 7010<sup>TM</sup> blue tinted glass available  
from Pittsburgh Plate Glass Industries, Pittsburgh,  
15 Pennsylvania. Graphs illustrating the percent transmission  
of both ultraviolet and visible light for a 2.3 mm thick  
pane of SOLEXTRA 7010<sup>TM</sup> glass are shown in Figs. 22a and  
22b. SOLEXTRA 7010<sup>TM</sup> glass is highly visibly transmitting  
at the 2.3 mm thickness, i.e., 83% transmission overall  
20 using a Standard Illuminant C and a photopic detector (Fig.  
22b). Also, this glass appears light blue in transmission  
and strongly absorbs UV radiation below about 340 nm (Fig.  
22a). At this thickness, Solextra 7010<sup>TM</sup> passes only about  
2% of the incident solar energy in the 250-350 nm range. In  
25 the 350-400 nm region, it passes about 67% of the incident  
solar energy.

Alternately, glass panel 12d may be formed from  
SUNGLAS<sup>TM</sup> Blue, a blue tinted glass from Ford Glass Co.,  
Detroit, Michigan. The spectral transmission for a 3 mm  
30 pane of SUNGLAS<sup>TM</sup> Blue, a blue tinted glass is shown in  
Figs. 23a and 23b. This glass is highly visibly

1 transmitting at this thickness, i.e., 72% transmission  
overall with Standard Illuminant C and a photopic detector  
(Fig. 23b), appears light blue in transmission and strongly  
absorbs ultraviolet radiation below about 330 nm (Fig. 23a).  
5 Such thickness of SUNGLAS<sup>TM</sup> Blue, a blue tinted glass passes  
only about 11% of the incident solar energy in the 250-350  
nm range and 67% of the incident solar energy in the 350-400  
nm range.

10 The above specialized glasses may also be used for  
second glass panel 12e or both panels 12d and 12e. Whether  
or not to use such specialized glass in both panels 12d and  
12e is dictated by the degree of UV radiation protection  
desired, and by the degree of attenuation allowable in  
15 visible transmission of light that is concurrent with use of  
even thicker panes or multiple panes of blue tinted or  
similar light filtering panels.

20 Mirror assembly 85 incorporating one or more blue  
glass panels provides a unique advantage. As described  
above, UV radiation stabilizers may be added to enhance the  
UV radiation stability of an electrochromichromic solution  
used in a rearview mirror assembly. Broad UV radiation  
stabilizers such as CYASORB 24<sup>TM</sup> from American Cyanamid  
Company of Wayne, New Jersey, UVINUL D-50<sup>TM</sup> from BASF  
Wyandotte Corporation, Parsippany, New Jersey, or TINUVIN  
25 327<sup>TM</sup> from Ciba Geigy, Hawthorne, New York, impart a yellow  
color to electrochromic or electrochemichromic solutions or  
materials, especially when they are added in high  
concentrations where they are most effective in protecting  
UV vulnerable materials. Yellow is aesthetically  
30 displeasing in many applications and is particularly  
displeasing when used in rearview mirrors. Also, when

1 electrochemichromic solutions are exposed to prolonged  
dosages of high intensity UV radiation, such as occur during  
natural weathering in sunny climates, those solutions  
frequently turn a yellowish hue which is aesthetically  
5 displeasing to the consumer. It has been found that use of  
specialized blue glass, such as that described above, allows  
use of higher concentrations of broad UV radiation  
stabilizers in electrochemichromic solutions than otherwise  
would be consumer tolerable due to yellowing.

10 As an example of an electrochemichromic device  
constructed according to Fig. 14, an electrochemichromic  
solution was formed from 0.025M methylviologen perchlorate,  
0.025M 5,10-dihydro-5,10-dimethylphenazine, 0.025M  
tetraethylammonium perchlorate and 12.5% wt/vol CYASORB 24<sup>TM</sup>  
15 UV radiation stabilizer, all dissolved in  
2-acetylbutyrolactone. When filled in cavity 18 of  
embodiment 85 as shown in Fig. 14, cavity 18 having a 150  
micron thickness and using 15 ohms/sq indium tin oxide (ITO)  
transparent coatings 13a, 17a and with glass panels 12d and  
20 12e both fabricated of 1.6 mm standard, clear, soda lime  
glass laminated together with a commercially available,  
clear PVB interlayer 12c SAFLEX<sup>TM</sup> SR#11 from Monsanto  
Company of St. Louis, Missouri, at zero potential and with a  
silver mirror reflector such as reflective layer 26 behind  
25 the assembly, the light reflected off mirror embodiment 85  
has a distinct yellow tint and measures about 80%  
reflectivity using Standard Illuminant A and a photopic  
detector. Because consumers in automobiles are accustomed  
and appreciative of "silvery" reflection such as is found on  
30 interior and exterior automotive mirrors of conventional  
design, the marked yellow tint makes use of high

1 concentrations of broad UV radiation absorbers commercially  
disadvantageous. Yet, such high concentrations of UV  
absorbers have the advantage of affording greater UV  
protection and, therefore, prolong the commercial life of  
5 electrochromic rearview mirror devices, particularly  
when used on the outside of a vehicle.

However, when a 2.3 mm pane of SOLEXTRA 7010<sup>TM</sup> was  
substituted as the first glass panel 12d, with all other  
factors being the same for the example of embodiment 85 as  
10 described above, the reflection as seen in the mirror  
reflector was no longer yellow but had a color or tint  
described as gun metal blue to neutral silvery. This is a  
much more acceptable and commercially desirable reflective  
color than the yellowish tint previously obtained. Because  
15 SOLEXTRA 7010<sup>TM</sup> glass panel 12d naturally filters out yellow  
light thereby absorbing undesirable yellow tint, the  
integrated reflection at zero potential in this version of  
the assembly is lower than that using clear glass, i.e.,  
about 63% reflectivity using Standard Illuminant A and a  
20 photopic detector. However, such transmission is still  
sufficiently high to allow successful use in vehicles,  
particularly as outside mirrors.

Yet another advantage is obtained using embodiment  
85 and the specialized glass panels 12d or 12e therein.  
25 Blue mirrors are particularly well-suited to night driving.  
Fig. 24 illustrates the relative spectral power output  
versus wavelength of a CIE Standard Illuminant A and for CIE  
Standard Illuminant C. Illuminant A is a Planckian radiator  
at 2856K and, thus, is similar to an automobile headlamp.  
30 Illuminant C provides light similar to average daylight.  
Also included on Fig. 24 are the wavelengths of light which



1 form the main bands of color in the visible spectrum. By  
 day, rearview mirror illumination is natural daylight  
 (similar to Illuminant C). By night, however, mirror  
 illumination will be that of headlamp output (similar to  
 5 Illuminant A) superimposed upon nighttime ambient light  
 which is essentially spectrally unbiased. Vision from a  
 mirror is also dependent on the spectral sensitivity of the  
 driver's eye. The spectral sensitivity of the human eye  
 depends on its light adaptation. If bright adapted, vision  
 10 is photopic and the spectral sensitivity is as shown in Fig.  
 25. If dark adapted, however, vision is scotopic and  
 sensitivity shifts toward the blue. Between these two  
 extremes vision is mesopic. Almost all night driving is in  
 the mesopic range of adaptation because the reflection of  
 15 the driver's own headlights from the road provide sufficient  
 illumination to maintain the adaptation level above the  
 scotopic range even on a very dark, unlit road. Because a  
 headlamp emits efficiently in the yellow/orange/red region  
 of the visible spectrum, but relatively poorly in the blue  
 20 region as shown in Figs. 24 and 25, and because a driver's  
 eyes when driving at night are somewhat more sensitive to  
 blue light, mirrors which optimize reflectance in the blue  
 spectral region but minimize reflectance in the  
 yellow/orange/red region best match human eye sensitivity in  
 25 day and night conditions, are most efficient at reducing  
 headlamp glare and are desirable as both inside and outside  
 rearview mirrors. Therefore, embodiment 85, which includes  
 the specialized tinted glass panel or panels, is efficient  
 in absorbing or filtering out substantially more light in  
 30 the yellow/orange/red regions of the visible spectrum than  
 in other regions of the visible spectrum. It tends to mask

1 yellowness due to any inclusion of UV radiation absorbers,  
or due to any degradation of the EC or ECC material itself,  
efficiently absorbs headlamp glare, provides a pleasing,  
attractive reflective color, and allows matching to visible  
5 blue tinted colors on outside mirrors when one side of the  
vehicle has an electro-optic mirror assembly for the driver  
and the other has a conventional, blue tinted,  
passenger-side mirror. In addition, the blue tinted  
embodiment 85 of the present mirror assembly is more restful  
10 on a user's eyes since any yellowness otherwise present in  
an electro-optic mirror assembly incorporating UV radiation  
stabilizers is a more efficient reflector of light from a  
yellow headlight and, thus, would reflect more glare to a  
user's eyes than a comparable blue tinted mirror. Also, a  
15 commercially useful advantage of SOLEXTRA 7010<sup>TM</sup> and  
SUNGLAS<sup>TM</sup> Blue glass panels is that they are relatively  
inexpensive, namely, generally about two to three times the  
already low commodity cost of conventional, clear, soda lime  
glass.

20 Alternately, SunBlue<sup>TM</sup> glass from Asahi Glass  
Company, Tokyo, Japan, can be used for one or both panels  
12d and 12e. SUNBLUE<sup>TM</sup> is a blue tinted float glass  
incorporating added iron content and has a visible light  
transmission of 83% at a 3 mm thickness (per JIS-R-3106) and  
25 a UV radiation cutoff below about 330 nm.

Also, SUNGLAS<sup>TM</sup> Green from Ford Glass, Detroit,  
Michigan, a green tinted glass, could be used for either or  
both of glass elements 12d and 12e in embodiment 85. As  
shown in Fig. 26b, such glass, in a 3 mm thickness, is  
30 highly light transmitting in the visible spectrum, i.e., 82%  
transmission overall with Standard Illuminant C and a

1 photopic detector. It is also slightly green tinted and  
cuts off UV radiation transmission below about 330 nm as  
shown in Fig. 26a. This glass in such thickness transmits  
only about 6% of the incident solar energy in the 250-350 nm  
5 region, and about 60% in the 350-400 nm region.

A preferred material for the interlayer 12c of  
embodiment 85 is commercially available polyvinylbutyral  
(PVB) sheeting such as SAFLEX<sup>TM</sup> SR#11 PVB mentioned above.  
Such commercially available PVB sheeting is commonly used in  
10 automotive and architectural products and is formed by  
combining PVB resin with added UV absorbers, as described  
earlier. Such commercially available polyvinylbutyral (PVB)  
sheeting is heavily plasticized with at least about 19 parts  
of plasticizer per 100 parts of polyvinylbutyral resin using  
15 plasticizers such as triethyleneglycol dihexoate,  
triethyleneglycol di-2-ethyl butyrate, tetraethyleneglycol  
di-n-heptanoate, di-n-hexyl adipate, butyl benzyl phthalate,  
and dibutyl sebacate. Figs. 27a and 27b illustrate the  
ultraviolet and visible spectral transmission of a sheet of  
20 SAFLEX<sup>TM</sup> SR#11 PVB adhered between two 1.6 mm conventional,  
clear, soda lime glass panels. Such a laminated assembly,  
using clear glass and SAFLEX<sup>TM</sup> SR#11, transmits only about  
8% of the incident solar energy in the 250-350 nm region and  
about 54% of such energy in the 350-400 nm region. When  
25 laminated, SAFLEX<sup>TM</sup> SR#11 sheeting is water clear in light  
transmission.

In general, various forms of SAFLEX<sup>TM</sup>  
polyvinylbutyral sheeting interlayers are acceptable for use  
in this invention as UV reducing interlayers. These include  
30 SAFLEX SR<sup>TM</sup>, SAFLEX TG<sup>TM</sup> and SAFLEX TL<sup>TM</sup> sheeting in  
thickness ranges between about 0.015 and 0.060 inch.

1 Thicker PVB interlayers provide better UV radiation  
shielding but may cause visible distortion. Yet, thicker  
sheeting is "acceptable if due care is taken during  
lamination. Generally, such SAFLEX<sup>TM</sup> sheeting is preferably  
5 shipped and stored in a refrigerated or cold condition to  
prevent the sheeting from sticking to itself while easing  
handling and use. Other commercially available clear PVB  
sheeting can be used. For instance, an architectural  
composition such as BUTACITE<sup>TM</sup> 14 NC-10 clear PVB sheeting  
10 from E. I. duPont de Nemours and Company of Wilmington,  
Delaware is a suitable choice. BUTACITE<sup>TM</sup> is plasticized  
polyvinylbutyral which is plasticized with  
tetraethyleneglycol di-n-heptanoate, with a plasticizer  
content (parts/100 parts resin) of about 38.5 or  
15 thereabouts. When laminated between two panels of 2.3 mm  
conventional, clear, soda lime glass as shown in Figs. 35a  
and 35b, BUTACITE<sup>TM</sup> 14 NC-10 clear PVB sheeting transmits  
less than 0.1% of the incident solar energy in the 250-350  
nm region and only about 25% in the 350-400 nm region.  
20 Alternatively, BUTACITE<sup>TM</sup> 140 NC-10, an automotive  
composition or BUTACITE<sup>TM</sup> 14 UV clear, an architectural  
composition PVB sheeting can be used.

Alternately, a blue or blue/green tinted  
interlayer 12c' may be substituted to form embodiment 85' of  
25 the mirror assembly as shown in Fig. 14. Preferably,  
BUTACITE<sup>TM</sup> Cobalt Blue 0547800 polymeric interlayer sheeting  
available from E. I. duPont de Nemours and Company of  
Wilmington, Delaware can be used. The ultraviolet and  
visible spectral transmission of BUTACITE<sup>TM</sup> Cobalt Blue  
30 sheeting, when laminated between two 2.3 mm standard, clear,  
soda lime glass panels is shown in Figs. 28a and 28b. Such

1 sheeting is a highly light transmitting polymeric material  
having 78% overall visible light transmission with  
Illuminant C and a photopic detector (Fig. 28b). It is blue  
in tint and highly absorbing in the UV radiation range below  
5 about 375 nm (Fig. 28a). It transmits only 0.01% of the  
incident solar energy in the 250-350 nm region and about 24%  
of such energy between 350 and 400 nm. By reason of its  
blue tint, BUTACITE<sup>TM</sup> Cobalt Blue sheeting also provides the  
advantage of masking yellowness in the mirror to provide a  
10 commercially acceptable silvery or silver-blue reflection  
from assembly 85', while reducing headlamp glare and also  
matching existing blue exterior rearview mirrors commonly  
used in many vehicles.

BUTACITE<sup>TM</sup> Cobalt Blue sheeting could be used  
15 alone or in combination with one or both panels 12d, 12e of  
embodiment 85 being specialized blue or green tinted glass.  
Other suitable blue tinted polymeric sheeting interlayers  
include BUTACITE<sup>TM</sup> Automotive Blue Green 0377800, BUTACITE<sup>TM</sup>  
Automotive Green Blue 1107800 and BUTACITE<sup>TM</sup> Light Blue  
20 Green 0377300 also available from E. I. duPont in  
Wilmington, Delaware. In addition, SAFLEX<sup>TM</sup> Blue Green  
377300 available from Monsanto Company of St. Louis,  
Missouri may be used. The ultraviolet and visible spectral  
transmission of SAFLEX<sup>TM</sup> Blue Green 377300 sheeting is shown  
25 in Figs. 29a and 29b. Alternately, SAFLEX<sup>TM</sup> Cool Blue  
637600 or SAFLEX<sup>TM</sup> Solar Blue 755800 polymeric sheeting  
could also be used.

With reference to Fig. 15, another embodiment 95  
of the electro-optic rearview mirror assembly of the present  
30 invention, where like numerals indicate like parts to those  
described above, incorporates a single glass panel 97 having

1 parallel front and rear surfaces but formed from one of the  
blue or green tinted specialized glasses described above in  
connection with embodiments 85 and 85'. Thus, for example,  
front glass element 97, which also includes a coating of  
5 indium tin oxide 13a on its rear or inner surface 13, may be  
formed from SOLEXTRA 7010<sup>TM</sup> blue tinted glass, SUNGLAS<sup>TM</sup>  
Blue glass, SUNBLUE<sup>TM</sup> glass or SUNGLAS<sup>TM</sup> Green glass. When  
the blue tinted glasses are used, the resultant yellow  
absorbing light advantages described above in connection  
10 with embodiments 85 and 85' result in embodiment 95 as well.  
These glasses are highly efficient in absorbing or filtering  
out substantially more light in the yellow/orange/red  
regions of the visible spectrum than in other regions of the  
visible spectrum. With reference to the visible spectrum in  
15 Fig. 24, such specialized glasses preferentially absorb  
visible light with wavelengths generally higher than about  
560 nm. In other respects, the embodiment 95 remains  
substantially the same as embodiment 60 of the mirror  
assembly. Optionally, panel 97 could be a panel of  
20 specialized blue or green tinted safety glass that has been  
tempered and/or toughened by conventional means which  
include thermal tempering, contact tempering and chemical  
tempering.

An alternate form 100 of the UV radiation reducing  
25 embodiment 65 shown in Fig. 9 is illustrated in Fig. 16.  
Mirror assembly 100, where like numerals indicate like parts  
to those described above, includes a UV absorbing paint or  
lacquer which is transparent to light in the visible  
spectrum and may be applied as coatings 102, 104 on one or  
30 both of the inwardly facing surfaces of glass elements 12a,  
12b or 12d, 12e. These are the surfaces of the glass panels

1 which face one another and adhering interlayer 12c. A  
preferred UV absorbing lacquer is PC-60 from American Liquid  
Crystal Chemical Corporation of Kent, Ohio which is a  
solvent based urethane with added UV stabilizers. The  
5 ultraviolet spectral transmission of an approximately 32  
microns thick coating of PC-60 lacquer when applied to one  
surface of a 1.6 mm thick single panel of conventional,  
clear, soda lime glass is illustrated in Fig. 30. When  
applied as a coating, PC-60 is highly visibly transmitting,  
10 i.e., about 89% overall transmission with Illuminant C and a  
photopic detector, has a slight yellow tint, and absorbs  
sharply in the UV radiation region below about 390 nm.  
Between 250 and 350 nm, such a coating of PC-60 lacquer  
transmits essentially none of the solar energy incident in  
15 that region. For incident solar energy between 350 nm and  
400 nm, PC-60 lacquer transmits only about 5%. Overall,  
such a coating of PC-60 lacquer transmits only about 3% of  
the incoming solar energy in the 250-400 nm region.

20 An alternate UV absorbing lacquer is ZLI-2456  
mentioned above in layer 70 and useful to form embodiment  
100' (Fig. 16). A 12 microns thick coating of ZLI-2456  
transmits only about 2% of the incident solar energy in the  
250-350 nm region, and only about 9% of the solar energy  
normally incident between 350 and 400 nm. ZLI-2456 is  
25 slightly more yellowish in color and transmission than is  
PC-60 lacquer. Of course, UV absorbing paint/lacquer  
coatings such as those described above may be used with UV  
absorbing/filtering interlayers 12c or 12c' as described  
above, or when either of glass panels 12a, 12d or 12b, 12e  
30 are formed from blue or green tinted specialized glass as  
described above. Indeed, in a preferred form of embodiment

100, glass panel 12d will be formed from SOLEXTRA 7010<sup>TM</sup> or  
SUNGLAS<sup>TM</sup> Blue glass while the electro-optic media in space  
18 will include UV absorbing additives as described above.  
The ultraviolet spectral transmission of ZLI-2456 is shown  
in Fig. 31.

As a specific example of mirror assembly 100 shown  
in Fig. 16, an electrochromic solution was formulated  
consisting of 0.02M methylviologen hexafluorophosphate and  
0.02M 5,10-dihydro-5,10-dimethylphenazine dissolved in  
2-acetylbutyrolactone. To this was added 12.5% wt/vol  
CYASORB 24<sup>TM</sup> UV radiation absorber. This was filled into a  
150 micron thick cavity between panels 16, 12b of ITO  
transparent coated, 1.6 mm thick, conventional, clear, soda  
lime glass. The ITO coating on each glass panel was 15  
ohms/sq and had a visible transmission of 85%. A coating of  
UV absorbing ZLI-2456 lacquer was spray coated on the front  
facing surface 103 of rear glass panel 12b and on the rear  
facing surface 101 of front glass panel 12a each to a  
thickness of about 11 microns. Glass panels 12a, 12b were  
then laminated by an interlayer 12c of SAFLEX<sup>TM</sup> SR#11 PVB  
sheeting. When tested under mercury UV radiation lamps at a  
temperature of about 80° C. for a period of approximately  
two weeks, such a mirror assembly was found to be  
exceptionally UV radiation stable. Integrated irradiation  
in the 295-400 nm region within the UV radiation chamber  
used to accelerate natural weathering was around 100W/m<sup>2</sup>.  
Initially electrochromic mirror devices with such UV  
and anti-scatter protection had a reflection of  
approximately 81% at zero potential which dimmed to a  
reflectivity of approximately 8% when one volt potential was  
applied across ITO coatings 13a, 17a which enclose the



1 electrochemichromic solution. After over 336 hours in the  
UV radiation chamber, the zero potential reflectivity  
remained high at around 80% and the mirror continued to dim  
to about 8% reflectivity when one volt was applied. The  
5 appearance of the mirror remained essentially unchanged  
after such prolonged exposure to high intensity ultraviolet  
radiation. Also, when the safety performance of the mirror  
assembly was tested by impacting it with a 0.9 kg steel ball  
dropped from a height of 1 meter, the SAFLEX<sup>TM</sup> SR#11  
10 laminating interlayer securely retained all shards of glass  
such that they did not fly away and such that they remained  
securely held to the laminate interlayer. Also, the  
SAFLEX<sup>TM</sup> SR#11 laminate interlayer did not fracture nor tear  
and was effective in ensuring that contact with chemicals  
15 used within the electrochemichromic mirror assembly is  
minimized should the mirror glass break in an accident.  
Because of the high concentration (12.5% wt/vol) of broad UV  
absorber CYASORB 24<sup>TM</sup> used in this embodiment, and because  
of the slight yellow tint inherent to ZLI-2456 UV absorbing  
20 lacquer, the reflection from this example of mirror assembly  
100 had a somewhat yellow tint which is cosmetically  
undesirable in some applications. However, when the front  
glass panel 12a was replaced with a blue tinted glass panel  
12d as described in embodiment 85, the benefits described  
25 above were achieved. Specifically, when a 2.3 mm panel of  
SOLEXTRA 7010<sup>TM</sup> glass was used as front glass panel 12d,  
reflectance at zero potential remained close to its initial  
64% in spite of over 336 hours of UV accelerated weathering  
testing as mentioned above. Because of the use of blue  
30 tinted glass, the reflector looked more silvery-blue and was  
more consumer acceptable. Also, when dimmed by applying one

1 volt to the transparent coatings 13a, 17a, the mirror  
continued to dim to its low reflection state of about 7%  
reflectivity, even after prolonged exposure to the intense  
UV radiation.

5 Also with reference to Fig. 16, an alternate  
embodiment 110 substitutes different layers for  
paint/lacquer layers 102, 104 preferably in the form of a  
polymeric film such as clear SCOTCHTINT<sup>TM</sup> SH2CLX available  
from 3M Corporation, St. Paul, Minnesota. Such SCOTCHTINT<sup>TM</sup>  
10 film may be adhered as layers 112, 114 to one or both of the  
inner facing surfaces of glass panels 12a, 12b or  
specialized glass panels 12d, 12e as described above, said  
placement on inner surfaces having the added advantage of  
protecting the potentially scratchable polymeric film behind  
15 glass panels 12a, 12d. Film layers 112, 114 (Fig. 16)  
provide assembly 110 with similar UV reducing advantages  
while maintaining strength and scatter preventing advantages  
due to the laminate front assembly as in embodiments 100 and  
100'. The ultraviolet spectral transmission of a single  
20 layer film of SCOTCHTINT<sup>TM</sup> SH2CLX adhered to a sheet of 1.6  
mm conventional, clear, soda lime glass is shown in Fig. 32.  
SCOTCHTINT<sup>TM</sup> SH2CLX is a highly visibly transmitting film,  
i.e., about 82% overall transmission using Illuminant C and  
a photopic detector. It is also clear and absorbs sharply  
25 and intensely in the UV region below about 380 nm.  
Preferably, SCOTCHTINT<sup>TM</sup> SH2CLX film is used in a form  
including a pressure sensitive adhesive applied to one  
surface such that it may be easily adhered to the rear  
facing surface of glass panel 12a or 12d and the front  
30 facing surface of glass panel 12b or 12e. Likewise, such  
polymeric film adds to the anti-scatter effect of the mirror

assembly 110 by retaining shards or splinters from glass panel 12a, 12d should it be broken upon impact. Also, by serving as a barrier film, they are effective in ensuring that contact with the chemicals used within the electro-optical mirror is minimized should the mirror glass break in an accident. Alternately, polymeric film such as SCOTCHTINT<sup>TM</sup> SH2CLX may be used in combination with clear or tinted UV reducing interlayers 12c or 12c' such as SAFLEX<sup>TM</sup> as described above.

As an alternative to using polymeric sheeting 112, 114 in mirror assembly embodiments 100, 100' or 110 as described above in Fig. 16, a UV curable, pourable adhesive can be used to retain the glass panels 12a, 12b or 12d, 12e together while simultaneously reducing UV transmission as embodiment 120 (Fig. 16). A suitable ultraviolet curing polyurethane adhesive modified so as to be UV curable is NORLAND NOA 65<sup>TM</sup> available from Norland Products, Inc., New Brunswick, New Jersey, which is water clear, highly transparent to visible light, includes a moderate modulus of elasticity when cured such that it is not overly brittle and does not fracture upon impact, and includes an index of refraction of 1.52 matched perfectly to that of soda lime glass (which has a refractive index of 1.52). NORLAND NOA 65 also adheres well to glass, is of relatively low viscosity (1,200 centipoise) such that it easily pours and spreads between two glass panels to allow lamination once cured. It also has a relatively low modulus of elasticity (20,000 psi). Its ability to be cured with UV radiation is well-suited to manufacturing processing. Fig. 33 illustrates the ultraviolet spectral transmission of a 35 microns thick coating of cured NORLAND NOA 65<sup>TM</sup> on a 1.6 mm

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1 conventional, clear, soda lime glass panel. Ultraviolet  
radiation transmission is cut off below about 310 nm while  
only about 19% of the incident solar energy in the 250-350  
nm region is transmitted while about 62% of the incident  
5 solar energy in the 350-400 nm region is transmitted.

Alternately, Norland NOA68, also a polyurethane  
adhesive modified so as to be UV curable and also available  
from Norland Products, Inc., can be used instead of NORLAND  
NOA 65. NORLAND NOA 68<sup>TM</sup> has a refractive index of 1.54  
10 matched closely with clear soda lime glass. It has a  
modulus of 20,000 psi when cured and has an excellent  
adhesion to glass. NORLAND NOA 61<sup>TM</sup>, which is a  
polyurethane adhesive modified so as to be UV curable, can  
also be used although, with a modulus when cured of 150,000  
15 psi, it is somewhat more brittle. Alternately, DYMAX  
LIGHT-WELD 478<sup>TM</sup> acrylic adhesive available from Dymax  
Corporation, Torrington, Connecticut can be used. This is a  
UV curing acrylic of Shore D hardness 65 that has a  
refractive index of 1.507 which is very close to that of  
20 soda lime glass when cured. Alternately, conventionally  
known UV curing optical epoxies, preferably of low modulus  
or with their modulus reduced through addition of reactive  
diluent and reactive flexibilizers, as is commonly known,  
can be used.

25 Should it be desired to further reduce the modulus  
of elasticity of the cured adhesive, clear plasticizers or  
clear low molecular weight epoxies can be added to the UV  
curing adhesives so that they are less brittle after curing,  
and such that they have even better lamination safety  
30 performance. For example, cyclohexanedimethanol diglycidyl  
ether such as HELOXY MK107<sup>TM</sup> from Wilmington Chemical

1 Corporation of Wilmington, Delaware can also be added to  
NORLAND NOA 61<sup>TM</sup>, NOA 65<sup>TM</sup> or NOA 68<sup>TM</sup> in quantities up to  
30% wt/wt or more (i.e., % grams of MK107 added to grams of  
NOA61, etc.) to plasticize them. HELOXY MK107<sup>TM</sup> has a  
5 refractive index close to 1.48 which is also well-matched to  
that of clear soda lime glass. At high concentration of  
added MK107, the UV cured NOA61, NOA65 or NOA68 materials  
are quite flexible and somewhat elastic such that they are  
well-suited for use as anti-lacerative layers and as  
10 laminate interlayers.

As an alternative to the UV curing adhesives  
described above, thermally or catalytically cured adhesives  
can also be used to retain glass panels 12a, 12b and 12d,  
12e together while simultaneously acting as a UV radiation  
15 reducing agent. As with the UV curing adhesives, the  
thermally or catalytically cured adhesives are preferably  
water clear, highly transparent to visible light, closely  
matched to the index of refraction of glass, while being of  
moderate modulus of elasticity when cured so as not to be  
20 overly brittle nor to fracture upon impact and thus impair  
retention of any glass fragments or shards. A suitable  
system includes a modified epoxy adhesive formed from 15%  
wt/wt EPON 828<sup>TM</sup> epoxy resin, mentioned above in embodiment  
10, 35% wt/wt HELOXY MK107<sup>TM</sup>, and 50% wt/wt CAPCURE 3-800<sup>TM</sup>  
25 mercaptan curing agent available from Diamond Shamrock  
Chemicals Company, Morristown, New Jersey. These  
ingredients are mixed together in a container and  
subsequently spun in a centrifuge at approximately 4,500 rpm  
for about ten minutes to remove entrained air. The  
30 resultant viscous mixture is clear and is applied between  
panels 12a, 12b or 12d, 12e. The resultant assembly so

1 formed is fired at about 110° C. for about one hour followed  
by firing at 140° C. for a further hour. Such firing causes  
the adhesive mixture to cure to an adhering but moderate  
modulus of elasticity, somewhat flexible, optically clear  
5 laminate. The ultraviolet transmission of a 500 microns  
thick cured coating of this adhesive mixture, coated onto a  
0.063 inch conventional, clear, soda lime glass panel is  
shown in Fig. 34. Such material transmits about 35% of the  
incident ultraviolet solar energy in the 250-350 nm region  
10 thereby providing good inherent UV absorbing properties.

Also, it is possible to enhance the already good  
inherent UV radiation absorbing properties of these UV,  
thermally, or catalytically cured adhesives by adding any of  
the UV absorbing materials such as UVINUL D-50<sup>TM</sup>, UVINUL  
15 D-49<sup>TM</sup>, UVINUL 400<sup>TM</sup>, TINUVIN P<sup>TM</sup>, TINUVIN 327<sup>TM</sup>, TINUVIN  
328<sup>TM</sup>, or CYASORB 24<sup>TM</sup> to the liquid adhesives prior to  
their cure.

The UV, thermally, or catalytically cured  
adhesives can also be optionally dyed so that they have a  
slight bluish tint and provide the desirable properties for  
20 the electro-optic mirror assemblies including specialized  
blue tinted glass panels or blue tinted interlayers. For  
example, taking the specific adhesive mixture of  
EPON 828<sup>TM</sup>/HELOXY MK107<sup>TM</sup>/CAPCURE 3-800<sup>TM</sup> described above,  
25 such mixture can be dyed blue using NEOZAPON BLUE<sup>TM</sup> 807, a  
phthalocyanine dye available from BASF Wyandotte  
Corporation, Parsippany, New Jersey, added in about 0.5% to  
1% by weight. When laminated between two 0.063 inch thick  
panels of clear, conventional, soda lime glass, such a dyed  
30 mixture, at 0.5% dye concentration, was highly visibly  
transmitting (78% transmission using Illuminant C and a

1 photopic detector), was tinted blue, and was highly  
absorbing in the UV region with only 30% transmission of  
incident solar UV energy in the 250-350 nm region.

5 In any of the above mirror assembly embodiments,  
and especially those utilizing one or more panels of clear  
soda lime glass not already tinted blue or green as in  
embodiments 85, 85', 100', 110 or 120, a blue,  
electrochemically inert dye may be added to the  
electrochromic or electrochemichromic solution itself to  
10 provide the advantages of absorbing more light in the  
yellow/orange/red region of the visible spectrum than in  
other regions of the visible spectrum. Such a dyed assembly  
will provide similar advantages to those including  
specialized blue tinted glass or blue tinted interlayers.  
15 For example, a suitable material such as NEOPEN 808<sup>TM</sup>, a  
blue dye of the phthalocyanine type, is available from BASF  
Wyandotte, Parsippany, New Jersey. Such material, dissolved  
to a concentration of 0.1% wt/vol in propylene carbonate (a  
common solvent used in electrochemichromic solutions), and  
20 when placed in a 1 mm pathlength cell, transmits about 60%  
of the visible spectrum (Standard Illuminant C and a  
photopic detector), and transmits only about 9% of the  
incoming solar UV energy in the 250-350 nm region.

#### ELECTROCHROMIC VEHICULAR GLAZING

25 Referring now to the window or glazing assembly  
embodiment of the present invention, Fig. 37 illustrates a  
laminate, electrochromic window/glazing assembly 200 having  
a first optically transparent element 212 which is scatter  
and anti-lacerative protected with a resinous, polymeric or  
30 other coated or applied layer 214 on its inner surface 211.  
Layer 214 is preferably formed from

1 tear-resistant, resilient material such as plasticized  
polyvinylbutyral (PVB) sheeting having a preferred thickness  
of from about 0.005 inches to about 0.060 inches. Element  
212 is preferably formed from a sheet of conventional soda  
5 lime window glass having a preferred thickness of from about  
0.02 to about 0.25 inches as is second element 216, which is  
spaced slightly outwardly from first element 212 to define a  
gap or space 218 for receiving an electrochromic medium 220.  
Also, element 216 is generally located closest to the  
10 outside of the vehicle and, as such, is located closest to  
the solar source of UV radiation. Generally, elements 212  
and 216 are of compound, matched curvature. As explained  
hereinafter, elements 212, 216 may also be optically clear  
resinous, polymeric sheets to further prevent fragment  
15 scattering and lacerative injuries if broken, to further  
reduce UV transmission, and to reduce weight. Layer 214  
also provides ultraviolet protection for the interior cabin  
of the vehicle and protects against contact with whatever  
chemicals are used in electrochromic medium 220 if element  
20 212 should crack or break.

Space 218 is formed between the generally parallel  
or tangentially parallel outer surface 213 of first glass  
element 212 and inner facing surface 217 of second glass  
element 216. Preferably, each of the inner and outer  
25 surfaces 213, 217 is coated with a layer of indium tin oxide  
(ITO) which is substantially transparent to incident visible  
light yet is sufficiently electrically conductive to enable  
application of an electric field or voltage across space 218  
between ITO layers 213a, 217a. Layers 213a and 217a also  
30 can be other transparent conductors such as doped tin oxide,  
doped zinc oxide, and the like. Electrical energy is



1 provided by wire leads 22, 24 secured in conventional manner  
to the peripheral portions of ITO coatings 213a, 217a as  
shown in Fig. 37.

5 In order to confine and retain the electrochromic  
medium in gap 218, a peripheral seal 229, formed from an  
epoxy material which adheres well to the ITO coatings 213a,  
217a on glass surfaces 213, 217 is applied adjacent the  
periphery of glass elements 212, 216. A suitable epoxy  
sealing material is EPON 828<sup>TM</sup> epoxy sealant from Shell  
10 Chemical Company of Houston, Texas cured by polyamide based  
curing agents such as V-40<sup>TM</sup> curing agent from Miller  
Stephenson Company of Danbury, Connecticut. The epoxy is  
preferably silk screened onto the inner surface of the first  
glass element 212 or the second glass element 216 or onto  
15 both glass elements. The corresponding glass element is  
then placed face to face with the still tacky epoxy. Seal  
229 is then fully cured, typically by placing the assembly  
into an oven at 110° C. for three hours. Gap 218 can then  
be filled by a variety of means such as simple injection of  
20 electrochromically active material using a syringe. The  
various electrochromic media proposed for use with the  
electro-optic mirror are also suitable for use as the  
electrochromic medium 220. In addition, the electrochromic  
medium 220 can be one of the types described in the SAE  
25 Paper #900419, the reference to which is incorporated  
herein.

Fig. 37 depicts an embodiment of the present  
invention where element 216 is a laminated composite formed  
from a pair of glass panels 251, 252 like element 212. A  
30 specialized near-infrared reflector 250 can be directly  
deposited onto the inwardly facing surface 255 of panel 252.

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1 In this arrangement, element 252 protects reflector 250 from  
the outside environment and from abrasive damage as in car  
washes and the like. Reflector 250 (shown enlarged in Fig.  
38) preferably incorporates at least one semi-transparent  
5 elemental metal thin film 256 of physical thickness in the  
range of between about 80 angstroms to 300 angstroms and of  
sheet electrical resistance of no greater than about 8  
ohms/square. Elemental thin metal film 256 is  
preferentially sandwiched between optically transparent thin  
10 metal compound films 258a, 258b. Thin metal compound films  
258a, 258b may be metal oxide, nitride, halide or sulfide  
thin films. Among the possible thin metal compound films  
are the following: zinc oxide, titanium oxide, vanadium  
oxide, zirconium oxide, tungsten oxide, indium oxide,  
15 bismuth oxide, magnesium fluoride, cerium oxide, indium/tin  
oxide, tin oxide, zinc sulfide, silicon oxide and silicon  
nitride. As shown in Fig. 39, in an alternative embodiment,  
near infrared reflector 250 can be deposited onto a polymer  
sheet or film 253, which polymer sheet or film itself is  
20 capable of providing UV protection and shatter protection.

Layer 254 in Fig. 37 is an adhesive substance for  
bonding panels 251 and 252 together. Layer 254 may  
preferably be a specialized tear-resistant, resilient  
interlayer of thickness 5 mils or greater such as BUTACITE<sup>TM</sup>  
25 14 NC-10 plasticized PVB sheeting from E.I. duPont de  
Nemours and Company of Wilmington, Delaware which imparts UV  
protection to electrochromic medium 220 and imparts scatter  
protection directly to element 216, and indirectly to  
element 212. Layer 254 can act to contain the  
30 electrochromically active material contained in gap 218  
should outer panel 252 and panel 251 shatter under impact.

1 Also, should tinting be desired, then tinted plasticized  
polyvinylbutyral sheeting such as SAFLEX OPTICOLOR SYSTEM<sup>TM</sup>  
interlayers from Monsanto Company of St. Louis, Missouri can  
be used. Preferably, such tinting causes the assembly to  
5 appear blue or green in transmission. This preserves the  
natural color of the sky, spectrally filters yellow light  
and, thus, protects from solar glare, thereby enabling use  
of high concentrations of UV stabilizers and reducing UV  
transmission through the assembly as a whole and into the  
10 electrochromic medium in particular while simultaneously and  
synergistically providing safety protection against contact  
with broken glass and the chemicals used in the  
electrochromic medium.

15 A second embodiment 202 of the window glazing  
assembly invention is shown in Figure 40 where element 212  
is the laminated composite formed from glass panels 251,  
212. The specialized near-infrared reflector layer 250 is  
sandwiched between elements 251 and 252 on the inwardly  
facing surface of element 251. Thus, relative to the  
20 vehicle outside, layer 250 is below the electrochromic  
medium 220. Such a construction is less desirable than that  
shown in Figure 37 because layer 250 is not in a position to  
protect electrochromic medium 220 from the damaging effects  
of solar near-infrared and ultraviolet radiation.

25 Figure 36 shows the solar energy spectrum Air Mass  
2 that constitutes the solar load incident on an automobile.  
Most of the solar intensity for Air Mass 2 is between 300  
and 2100 nm. On the average, ultraviolet (UV) constitutes  
3% of solar radiation (up to 400 nm), while visible light or  
30 radiation is 48% (between 400 and 700 nm) and near-infrared  
(NIR) is 49% (between 700 and 2100). If a perfect filter

1 could be designed to reject all solar NIR radiation, nearly  
half of the solar energy could be rejected without any loss  
of visibility.

As a specific illustration of the benefit  
5 achievable through use of a specialized near infrared  
reflector in combination with an electrochromic medium, UV,  
luminous and solar transmission studies were performed on  
both an electrochromic cell alone and on the combination of  
commercially available heat mirror constructions with the  
10 same electrochromic cell. The cell was formed by  
sandwiching an electrochemichromic solution comprising;  
0.035 M ethylviologen perchlorate  
0.035 M 5,10-dihydro-5,10-dimethylphenazine  
5% wt/vol Uvinul<sup>TM</sup> 400 (2,4-dihydroxy-benzophenone)  
15 dissolved in a solvent comprising 75% 3-hydroxypropionitrile  
and 25% glutaronitrile. The cell gap was 135 microns. The  
ITO transparent conductors sandwiching the  
electrochemichromic medium were of half-wave (about 1500  
angstroms) thickness and of sheet resistance 15 ohms/square  
20 or thereabouts coated onto 0.043" thick soda lime glass  
elements. Measurements were taken over four spectral  
ranges, namely, ultraviolet (UV), visible, near-infrared  
(NIR), and solar (Air Mass 2), of the attenuating  
characteristics of this electrochromic cell construction,  
25 both when the cell was bleached and when it was colored  
under 1 volt applied potential. The results are summarized  
in Table A.

30

1

TABLE A

## Conventional Electrochemichromic Window

## Half-Wave ITO Electrodes

	UV 300-400 nm <u>%T/%R</u>	VISIBLE 400-800 nm <u>%T/%R</u>	NEAR-IR 800-2500 nm <u>%T/%R</u>	SOLAR 300-2500 nm <u>%T/%R</u>
Bleached	9%/5.5%	77%/10%	47%/17%	63%/13%
Colored (1.0 volt)	0.01%/5.3%	14%/6%	37%/16%	23%/10%

%T = Percent Transmission

%R = Percent Reflected

10

As can be seen from the data, this electrochemichromic window transmits about 63% of incident solar radiation when bleached and about 23% of incident solar radiation when fully colored under 1.0 volt applied potential.

15

Table B summarizes the results of similar measurements obtained when the electrochemichromic window cell of Table A was combined with a heat mirror glass commercially available from Cardinal Glass Inc. of Spring Green, Wisconsin in a manner similar to that shown in Figs. 37 and 38, but without any anti-lacerative layer 214.

20

TABLE BElectrochemichromic Window Combined  
with Cardinal Heat Mirror

## Half-Wave ITO Electrodes

	UV 300-400 nm <u>%T/%R</u>	VISIBLE 400-800 nm <u>%T/%R</u>	NEAR-IR 800-2500 nm <u>%T/%R</u>	SOLAR 300-2500 nm <u>%T/%R</u>
Bleached	7%/13%	64%/14%	24%/46%	46%/27%
Colored (1.0 volt)	0.1%/13%	12%/11%	18%/46%	14%/25%

30

The Cardinal Heat Mirror (see Figure 38) comprises a thin silver film 256 of thickness less than 300 angstroms incorporated in a multilayer thin film stack which includes

1 a sandwich of zinc oxide thin film layers 258a, 258b on  
glass panel 252. Note, from Table B, that combination of  
the Cardinal Heat Mirror with the electrochromic window  
allows preservation of a relatively high luminous visible  
5 transmission of 64% (of benefit for automotive glazing such  
as front, side, or rear windows where preservation of high  
transmittance in the bleached state may be of safety  
importance) while simultaneously significantly further  
reducing the total solar load transmitted into the  
10 automobile interior.

In the bleached state, use of the Cardinal Heat  
Mirror achieves a reduction in solar transmittance from 63%  
to 46% and, in the colored state, from 23% down to 14%.  
Similar benefits can be obtained by combining alternate thin  
15 film stacks to that utilized in the Cardinal Heat Mirror  
with the electrochromic window. However, it is  
important that the elemental metal layer 256 used therein  
has a high carrier density and high charge mobility so that  
its plasma edge rises early in the near-IR region thereby  
20 reflecting the maximum near-IR solar radiation. Sheet  
electrical resistance is preferably below about 8  
ohms/square or thereabouts. Optionally, and given that  
metal layer 256 is not contacting the electrochromic medium  
and, as such, is electrically isolated therefrom, electric  
25 current can be passed across metal layer 256 via wires or  
other electrical connections secured to layer 256 from the  
automobile electrical system for the purpose of heating and  
defrosting the glazing assembly when so desired during  
winter months and the like. The thin elemental metal layer  
30 256 preferably has a physical thickness between about 80  
angstroms and 300 angstroms. Below 80 angstroms, the

1 deposited coating is insufficiently continuous to yield good  
electrical conductivity and to achieve good near-IR  
reflectivity. Above 300 angstroms, the deposited thin  
5 elemental metal is overly opaque and overly luminous  
reflecting to be desirable for high transmittance  
applications, even when antireflected in a multilayer  
optical stack. These effects are illustrated in Figures 36A  
and 36B.

10 Figure 36A shows the % luminous transmission (with  
the source being Standard Illuminant A) as the thickness of  
a silver elemental metal film, deposited onto a soda lime  
glass substrate, increases in thickness from about 60  
angstroms to about 400 angstroms. Note that % luminous  
transmission falls off rapidly and dramatically with  
15 increasing thickness of the silver film. However, when a  
construction such as is shown in Figure 38 or 39 is used  
with layer 258a being 180 angstroms thick film of titanium  
dioxide (refractive index 2.5), and layer 258b also being a  
180 angstroms thick film of titanium dioxide (refractive  
20 index 2.5), and with these layers sandwiching a layer 256 of  
elemental silver, then, and as shown in Figure 36B, the  
thickness of the silver layer can be increased to 300  
angstroms, or thereabouts, while sustaining % luminous  
transmission above 50%.

25 For many automotive glazing constructions, and  
especially for those involving compound curvature, it is  
desirable that the specialized near-infrared reflector be  
deposited onto a flexible element like layer 253 in Fig. 39  
such as MYLAR<sup>TM</sup> polyester film available from E.I. duPont of  
30 Wilmington, Delaware. Such polyester film is typically  
supplied in film thicknesses ranging from 0.001 to 0.050

1 inches or thereabouts. There are several advantages to use  
of a flexible polymer element for heat mirror coating.  
Being flexible and polymeric, it can be readily conformed  
under modest temperature and pressure, thus facilitating  
5 constructions where the rigid elements 212, 216, 251, 252,  
and the like are of compound curvature such as commonly  
found for automotive glazing. Also, the flexible polymer  
film can form a barrier affording protection against  
chemical leakage should the typically glass elements it  
10 contacts break or crack.

Such heat mirror coated flexible polymer film like  
253 can be economically supplied coated on both surfaces  
with a conventional pressure-sensitive adhesive so that when  
sandwiched between glass as in the constructions  
15 contemplated in this invention, the flexible polymer film  
itself can afford a degree of safety protection to occupants  
in an accident. In addition, the polymer film itself can be  
a host for UV absorbers and so can supplement other UV  
attenuating means present in the construction as mentioned  
20 above regarding rearview mirrors (such as UV absorbers in  
solution in the electrochromic medium, such as glasses of  
increased iron oxide and/or cerium oxide content, use of a  
specialized UV absorbing glass for elements 212, 216, 251,  
252, etc.). Further, the polymer film may be tinted to  
25 facilitate construction of tinted electrochromic windows.

An example of a near-infrared reflector forming a  
heat mirror which is deposited upon a flexible polymer film  
and is suitable to combine with an electrochromic window to  
achieve the objectives of this invention is HM-55 film from  
10 Southwall Corporation of Palo Alto, California. HM-55  
includes a thin film coating of silver sandwiched between



indium oxide thin film layers, all in turn deposited onto a thin Mylar<sup>TM</sup> flexible polymer film. Table C summarizes the results obtained when the electrochromic window cell of Table A was combined with a HM-55 heat mirror film by application to the outer glass surface.

TABLE C

Electrochromic Window Combined  
with HM-55 Heat Mirror

Half-Wave ITO Electrodes

	UV 300-400 nm <u>%T/%R</u>	VISIBLE 400-800 nm <u>%T/%R</u>	NEAR-IR 800-2500 nm <u>%T/%R</u>	SOLAR 300-2500 nm <u>%T/%R</u>
Bleached	3.8%/43%	37%/46%	23%/77%	25%/58%
Colored (1.0 volt)	0%/43%	6%/44%	18%/77%	6%/58%

As indicated, the HM-55 film is relatively attenuating in the visible region so that this combination is best suited for applications such as an automotive sunroof where high bleached state transmittance is not necessary but where it is highly desirable to be darkly attenuating in the colored state and where exceptional solar performance in both the bleached and the colored states is desired. As Table C indicates, solar transmittance in the bleached state is only 25% and this decreases to a mere 6% when the electrochromic window is dimmed under 1.0 volt applied potential. Thus, the use of a thin elemental metal layer in combination with an electrochromic window (which itself is relatively solar transmitting in both the bleached and colored state) achieves exceptional solar performance for the combination. Note also that the UV transmission in the bleached state using HM-55 film is substantially reduced over that achieved with previously described designs, such

1 UV reduction being beneficial in avoiding degradation of  
interior trim such as seats, carpets, etc. Note also the  
low near-infrared solar transmittance through this assembly.  
Such low UV and near-IR transmittance, even in the bleached  
5 state, can have an important safety implication. The human  
eye is not sensitive to radiation in the UV and near-IR  
spectral region. Thus, it is important that UV and near-IR  
transmission be minimized to avoid eye damage, and  
particularly retinal damage, for consumers viewing the sky  
10 and the sun through the electrochromic window assembly.

As an alternative to HM-55, HM-77, HM-66, HM-44,  
and HM-33 heat mirror coatings on polyester film, all  
available commercially from Southwall Corporation of Palo  
Alto, California, can be used. HM-77 and HM-66 are low  
15 reflectance heat mirrors most suited to automotive glazing  
applications like front, side, and rear windows where high  
luminous transparency is of benefit. HM-44 and HM-33 are  
low transmittance heat mirrors most suited to automotive  
glazing applications such as sunroofs where high  
20 transparency is not a requirement. Also, all such heat  
mirror multilayer stacks could be deposited onto tinted  
polyester film to facilitate production of tinted  
electrochromic window assemblies. Alternatively, the heat  
mirror polyester films could be combined with tinted glass  
25 such as GRAYLITE<sup>TM</sup>, a dark gray tinted glass available from  
PPG Industries Inc., Pittsburgh, Pennsylvania.

Alternatively, the specialized near-infrared  
reflectors described above could be combined with  
specialized UV-absorbing glasses such as AZURLITE<sup>TM</sup>, a light  
30 aqua (blue-green) tinted glass available from Pittsburgh  
Plate Glass Industries, Pittsburgh, Pennsylvania, LOF

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TOP SECRET  
EZ-Koal<sup>TM</sup> glass which is a green tinted glass of increased cerium oxide and iron oxide content, available from Libbey Owens Ford of Toledo, Ohio, or with equivalent specialized UV-absorbing glasses as described above in connection with the electrochromic mirrors. Such specialized UV-absorbing glasses have a higher iron oxide content of within the range of about 0.2% to 0.9% by weight and/or a higher cerium oxide content of 0.2% to 0.9% by weight. Even higher iron oxide and/or cerium oxide contents, such as 1% to 2% or more, can be contemplated, for applications such as sunroofs, etc., where the dark tinting that accompanies such high levels of iron oxide and/or cerium oxide may not be product objectionable. For specialized UV absorbing glasses that have a high iron oxide content, it is desirable to maximize UV absorption by maximizing the ferric (Fe III) ion content of the glass. Alternately, a specialized UV absorbing glass of titanium dioxide content greater than 0.2 weight percent or thereabouts can be used.

The exceptionally high near-IR reflectances, and consequent beneficial climate control when combined with an electrochromic window, attained by specialized near-infrared reflectors is not achieved by standard low-E coatings such as semiconducting oxides which are used in architectural climate control. This is illustrated in Table D and in the plots on the graph of Figure 41 which contrast the performance achieved using a multilayer stacks, such as the Cardinal Heat Mirror and the HM-55 film described above and incorporating an elemental metal thin film to the performance attained with a low-E coating such as half-wave (1500 angstroms) and full-wave (3000 angstroms) ITO.

1

TABLE D

	UV 300-400 nm %T/%R	VISIBLE 400-800 nm %T/%R	NEAR-IR 800-2500 nm %T/%R	SOLAR 300-2500 nm %T/%R
Half-Wave ITO	78%/13%	86%/10%	64%/17%	77%/13%
Full-Wave ITO	74%/16%	83%/12%	71%/17%	72%/14%
Cardinal Heat Mirror	53%/11%	83%/7%	42%/45%	65%/23%
HM-55	36%/44%	52%/40%	14%/81%	36%/57%

Whereas the ITO coating merely reflects less than 20% of the near-infrared portion of the solar insolation in the 800-2500 nm region, the heat reflectors incorporating a thin elemental metal film significantly reflect near-infrared radiation in this region with the Cardinal Heat Mirror reflecting 45% solar near-infrared radiation and the HM-55 film reflecting 81% in this region. The reason for this good near-infrared reflectance performance is illustrated in Figure 41 which plots percent reflectance versus wavelength in the 800-2500 nm region for half-wave ITO, full-wave ITO, Cardinal Heat Mirror, and HM-55. The thin elemental metal film based near-infrared reflectors are seen to rise in reflectance earlier and sharper in the near-infrared region than what is achieved with the semiconducting ITO coatings. Thus, combination of thin elemental metal-based reflectors with electrochromic windows more closely approaches the ideal performance for automotive glazing which is independent control, via electrochromism, of visible light transmission while simultaneously achieving maximal (ideally 100%) reflectance of incoming near-infrared solar energy. In general, thin elemental metal-based reflectors useful to achieve the objectives of this invention reflect at least about 30% of Air Mass 2 near-infrared solar energy in the 800 nm to 2500 nm spectral range. The percent reflectance

of near-infrared solar energy for Air Mass 2 in the 800 nm to 2500 nm spectral range for silver thin elemental metal films ranging in thickness from about 60 angstroms to about 400 angstroms and deposited onto a glass substrate is plotted in Fig. 41A. As the graph shows, a silver film of at least about 60 angstroms, or thereabouts, thickness reflects at least about 37% of Air Mass 2 near-infrared solar energy in the 800 nm to 2500 nm spectral range. When a silver elemental thin film of thickness ranging from about 60 angstroms to 400 angstroms is sandwiched between two 180 angstroms titanium dioxide layers, with the resulting tri-layer stack itself deposited onto a glass substrate, the variation of percent reflectance of Air Mass 2 near-infrared solar energy in the 800 nm to 2500 nm spectral range versus thickness of the silver film is given in Fig. 41B. Note that the titanium dioxide layers have an anti-reflecting effect in this spectral region. For this stack design, a reflectivity in the 800-2500 nm spectral range for Air Mass 2 of at least about 30% is achieved for a silver film of at least about 75 angstroms or thereabouts.

Figure 42 illustrates another embodiment 206 of the invention, the performance of which is given in Table E.

TABLE E

UV Attenuating, Near-IR Reflecting, Safety Protected Electrochromic Window				
	UV 300-400 nm <u>%T/%R</u>	VISIBLE 400-800 nm <u>%T/%R</u>	NEAR-IR 800-2500 nm <u>%T/%R</u>	SOLAR 300-2500 nm <u>%T/%R</u>
Bleached	3.4%/10%	22%/26%	3.5%/29%	14%/27%
Colored (1.0 volt)	0%/10%	3.4%/26%	2.6%/29%	3%/29%

1 Element 216 consists of panels 251, 252. Panel 252 is a  
blue-tinted, UV-absorbing specialized glass (3 mm thickness)  
available from Ford Glass Company, Detroit, Michigan, under  
the trademark SUNGLAS<sup>TM</sup> BLUE. Layers 257a and 257b are  
5 blue-tinted plasticized polyvinylbutyral sheeting, each of  
sheet thickness 0.030", available from E.I. duPont de  
Nemours and Company of Wilmington, Delaware, under the trade  
name BUTACITE<sup>TM</sup> Cobalt Blue B140 0547800. Layer 250 is a  
specialized near-infrared reflector available from Southwall  
10 Corporation of Palo Alto, California, under the trade name  
HM-55 film. Element 212 and panel 251 were coated on their  
respective surfaces 213 and 217 with a transparent  
conducting layer of full-wave indium tin oxide (ITO) of  
thickness approximately 3000 angstroms and of 7 ohms/square  
15 or thereabouts sheet resistance. The interpane gap 218  
between elements 212 and 216 was about 135 microns in  
thickness. The electrochromic medium 220 was an  
electrochemichromic solution comprising:

20 0.035 M ethylviologen perchlorate  
0.035 M 5,10-dihydro-5,10-dimethylphenazine  
5% wt/vol UVINUL<sup>TM</sup> 400  
(2,4-dihydroxy-benzophenone)

dissolved in a solvent comprising 75% by volume  
3-hydroxypropionitrile and 25% glutaronitrile. Coloration  
25 was achieved by applying 1 volt potential across the  
electrochromic medium 220. Antilacerative layer 214 is a  
two-layer composite comprising an inner tear-resistant sheet  
of plasticized polyvinylbutyral and an outer abrasion  
resistant layer of polyester, and is marketed under the  
30 trademark BE 1028 by E.I. duPont, Wilmington, Delaware.

1 Layer 214 can also include silicone moieties  
chemically incorporated in the anti-lacerative composite to  
prevent condensation and/or beading up of condensed water on  
the coated front surface 211 of element 212, in high  
5 humidity conditions thereby providing an anti-fogging,  
anti-misting result. A material found useful as  
anti-lacerative, anti-fogging layer is silicone impregnated  
polyurethane supplied under the trade name CLARIFLEX<sup>TM</sup> by  
Saint-Gobain Vitrage of Paris, France. UV reducing  
10 additives such as those described above in connection with  
Fig. 2 may also be incorporated in the anti-lacerative,  
anti-fogging layer to increase the lifetime of the assembly.  
Alternately, element 212 may be fashioned from conventional  
soda lime glass, UV reducing specialized glasses, or polymer  
15 plastics. It is also possible to utilize thin film coatings  
or UV reducing paints or lacquers on at least one surface of  
front element 212 when the anti-lacerative, anti-fogging  
layer is incorporated. Likewise, it is possible to apply a  
near-infrared reflector incorporating a thin elemental metal  
20 film to front surface 211 of element 212.

The construction of Figure 42 is particularly  
suited towards automotive sunroofs. As can be seen from  
Table E, transmission into the vehicle interior is only 14%  
of the solar Air Mass 2 spectrum, even in the bleached state  
25 and this decreases to only 3% when the electrochromic medium  
is colored. Note that visible transmission is 22% in the  
bleached state (acceptable in an automotive sunroof where  
the driver or vehicular occupant will be viewing the outside  
bright sky through the sunroof) which decreases to only  
30 about 3.4% visible transmission when the electrochromic  
medium is colored under 1.0 volt applied potential

1 (desirable in that the driver or vehicular occupant  
perceives a significant visible attenuation when the  
electrochromic sunroof dims and also benefits from reduced  
solar glare). Further, and useful when both driving and  
5 parked, the total solar load transmitted into the car  
interior is drastically reduced, particularly when the  
electrochromic medium 220 is colored. Hence, the car can be  
parked for prolonged periods in a sunny climate without such  
a sunroof contributing significantly to heat-buildup in the  
10 car interior. Note also from Table E that UV transmission  
through the complete assembly 206 is very small when the  
device is bleached and is essentially eliminated when the  
device is colored. Such UV reduction is beneficial in  
avoiding degradation of interior trim such as seats and  
15 carpets.

The appearance of assembly 206, when viewed from  
the side of panel 252, is slightly but perceptively  
metallic-like in appearance whereas, when viewed from the  
side of layer 214, the appearance is more blue-like in  
20 transmission. This is a benefit in that, since panel 252 is  
on the exterior of the vehicle, assembly 206 has a more  
metallic appearance while, to the vehicular occupant,  
assembly 206 operates from a partial blue tint to a dark  
blue tint. Thus, the driver and occupants simultaneously  
25 benefit from a sense of privacy and from a sense of  
user-control over the sunroof tint. When dimming or dimmed,  
the change perceived from the outside of the vehicle is much  
less than that experienced viewing from the car interior to  
the outside sky. Thus, the outward appearance of the  
30 vehicle remains fairly constant (of benefit to designers who  
desire a style and color match of the sunroof or other



1 glazing to the rest of the vehicle) while, simultaneously,  
the driver or occupants perceive good value for their  
investment in a controllable-tint glazing element. Also,  
the blue tint of the assembly, particularly in its fully or  
5 substantially bleached states, as seen in transmission from  
the interior vehicular cabin to the outside sky is  
particularly advantageous in that such blue tint selectively  
and preferably absorbs glare from the sun which is  
predominantly yellow in color while simultaneously  
10 transmitting wavelengths in the blue and green region from  
400 nm to 560 nm, and so preserving the blue, natural color  
of the sky. Further, use of tinted means such as blue  
tinted glass, blue tinted polymer layers and blue dyes in  
the assembly allow use of increased concentrations of UV  
15 stabilizers and absorbers while avoiding the consumer  
undesirable yellow tint that usually accompanies such use of  
high concentrations of UV stabilizers and absorbers. In  
window assemblies, excellent UV stabilization is  
particularly important given that the electrochromic device  
20 will be exposed to intense UV solar radiation, typically  
while in its colored state.

Also, for additional scatter protection and  
safety, in any of the above disclosed mirror assembly  
embodiments, any of the glass panels of the assemblies could  
25 be formed from safety glass that has been tempered and/or  
toughened by conventional means including thermal, contact  
and chemical tempering. Also, such tempered, safety glass  
can be blue or green tinted to provide the advantages  
described above. In addition, layer 214 provides occupant  
30 protection against injury due to scattered glass or  
lacerative contact with broken shards and prevents immediate  
occupant and interior trim contact with the solvents and

chemicals used in electrochromic medium 220. Likewise, and particularly for applications such as a sunroof, sun visor, or shade band where sun glare reduction, good shading efficiency, and good thermal insulation performance is desirable, at least one of elements 212, 216, 251 and 252 can be formed from architectural glass such as SOLARBRONZE<sup>TM</sup>, a bronze tinted glass; SOLARGRAY<sup>TM</sup>, a gray tinted glass; GRAYLITE<sup>TM</sup>, a dark gray tinted glass; and SOLEX<sup>TM</sup>, a green tinted glass; all available from Pittsburgh Plate Glass Industries of Pittsburgh, Pennsylvania; SUNGLAS<sup>TM</sup> Gray, a gray tinted glass; and SUNGLAS<sup>TM</sup> bronze, a bronze tinted glass; available from Ford Glass Company, Detroit, Michigan; and with E-Z-Eye<sup>TM</sup>, a green tinted glass; available from Libby Owens Ford of Toledo, Ohio. Further, elements 212, 216, 251 and 252 can be coated with low-emittance monolithic architectural coatings such as SUNGATE<sup>TM</sup> 100, a low emittance, high transmittance coating available from Pittsburgh Plate Glass Industries of Pittsburgh, Pennsylvania; and SUNGLAS<sup>TM</sup> HR, a low emittance, high transmittance coating available from Ford Glass Company, Detroit, Michigan. Also, ECLIPSE<sup>TM</sup>, a pyrolytic Low-E coating available from Libby Owens Ford of Toledo, Ohio can be used. Further, elements 212, 216, 251 and 252 can be coated with vacuum deposited architectural coatings such as SOLARBAN<sup>TM</sup> available from Pittsburgh Plate Glass Industries of Pittsburgh, Pennsylvania, or can be coated with KOOLOF<sup>TM</sup>, a solar control coating available from Libby Owens Ford of Toledo, Ohio.

Further, perimetral coatings and darkened/color matched seals, as described in copending patent application serial no. 07/454,398, filed December 21, 1989, entitled

1 PERIMETER COATED, ELECTRO-OPTIC MIRROR, invented by Niall R.  
Lynam, the disclosure of which is hereby incorporated by  
reference herein, can be applied to window glazing  
constructions such as shown in Figs. 37, 40 and 43. For  
5 example, perimetal coatings, 310 and 311 of Fig. 43, of a  
conductive black frit or paint, can be applied around the  
perimeter of surface layers 213a and 217a so as to hide from  
view the seal 229 and the connection of electrical leads 22,  
24 to layers 213a, 217a. A suitable material is ENGLEHARD  
10 SC 6002 (# 6082), a platinum/palladium conductive ink  
available from Englehard Corporation of Iselin, New Jersey.  
Also, seal 229 can be color matched to any bezels, gaskets,  
encapsulants, or vehicular body moldings used to fix the  
electrochromic window assembly into a vehicle. For example,  
15 carbon black, in a nonconducting form, could be added to  
seal 229 in order to render it color matched to any black or  
dark rubber or plastic encapsulation means used to secure  
the electrochromic assembly into the vehicle. Alternately,  
perimetal coatings 410, 420, as shown by the dashed lines on  
20 Fig. 43, and formed from, for example, a frit material such  
as DRAKENFELD<sup>TM</sup> black enamel 24-1729 available from  
Drakenfeld Colors of Wilmington, Pennsylvania, can be used  
to obscure from view the seal/electrical means used in the  
assembly.

25 While several forms of the invention have been  
shown and described, other forms will now be apparent to  
those skilled in the art. Therefore, it will be understood  
that the embodiments shown in the drawings and described  
above are merely for illustrative purposes, and are not  
30 intended to limit the scope of the invention which is  
defined by the claims which follow.